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CONTENTS.

	PAGE
Council and Officers..	i-ii
General Notices :—	
Copyright	iv
Issue of Journal	iv
Changes of Address	iv
Papers and Articles	iv
Binding of Journals	iv
Reprints of Papers	iv
Abstracts	iv
Medals	v
Research Fund	v
Advertisements	v
Appointments Register	vi
Library	vi
Personal Notes and Special Notices	vi-vii

PAGE

Drilling and Production Methods in the Greater Seminole Field, Oklahoma, U.S.A. By G. HESELDIN, M.Sc., Assoc.M.Inst.C.E. 783

The Bearing of Base Exchange on the Genesis of Petroleum. By E. MCKENZIE TAYLOR, M.B.E., Ph.D., D.Sc., F.I.C. 825

Oilfield Practice in 1927. By A. BEEBY THOMPSON, O.B.E., M.I.Mech.E., M.Inst.M.M., F.G.S. 840

Notes on New Methods of Drilling in California. By A. E. COOKE CORBET 854

Eighth Congres de Chimie Industrielle 859

Reviews 861

Abstracts. Arranged by W. H. THOMAS, A.R.S.M. .. 311A

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

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Members whose subscription is not in arrear receive the Journal free of cost, and additional copies are charged at the rate of 7s. 6d. per part, unless otherwise stated. A member whose subscription is not paid by June 30th of the year for which it is due is considered to be in arrear.

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Authors of papers published in the Journal are entitled to receive 25 free reprints of their contribution. Further copies may be obtained on payment and orders for these should be sent to the Secretary when the manuscript is forwarded to the Editor. The free reprints do not include any discussion which may be published with the paper, but authors may have such discussion included in their reprints on payment of the additional cost.

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A medal and a prize of five guineas is awarded annually by the Council to that Student Member of the Institution who shall, in their opinion, have presented the best paper during the session.

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Applications from full Members of the Institution do not require a supporter.

Applications for grants from this fund will be considered in June and December of each year and must be received by the Secretary not later than June 1st or December 1st respectively. Application forms may be obtained from the Secretary of the Institution at Aldine House, Bedford Street, London, W.C. 2.

Advertisements. Advertisements are inserted in the Journal, and information as to terms, etc., can be obtained from Mr. Thomas Tofts, 30 Bank Chambers, 329, High Holborn, W.C. 1. (Telephone No. Hol. 4776.)

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PERSONAL NOTES OF MEMBERS AND SPECIAL NOTICES.

It is suggested that members send information regarding their movements to the Secretary, for insertion under this heading.

Mr. K. E. BENSUSAN has left U.S.A. and is now in Maracaibo, Venezuela.

Mr. R. L. C. BLEECK is now in England.

Mr. T. L. BONSTOW is now in Mexico.

Mr. R. P. BOLTON has returned to Italy.

Mr. H. C. CARTER is now in Burma.

Mr. A. E. C. CORBET has left for Burma.

Mr. F. G. CLAPP has left Persia and is now in France.

Mr. C. G. DIGBY is in Persia.

Mr. C. H. FLETCHER has returned from Cyprus.

Mr. W. E. FRANKENBURG has left Burma and is now in England.

Mr. C. O. GRAHAM is now in Japan.

Mr. S. A. GUEST is home from Roumania.

Mr. R. H. S. HAYDON has left Ecuador and is now in Peru.

Mr. D. G. JONES is in Iraq.

Mr. G. LANSING has left Roumania and is now in U.S.A.

Professor P. N. KOGGERMAN has returned to Estonia.

Mr. W. MOORE has left for Venezuela.

Mr. A. F. C. Parker is in Persia.

Dr. E. PARSONS has left for British East Africa.

Mr. D. K. PETERS is now in U.S.A.

Mr. D. P. REES has left Assam and is in Burma.

Mr. T. ROBATHAN is now in Ecuador.

Mr. J. H. ROBERTSON has left Burma.

Mr. A. J. RUTHVEN-MURRAY is in Trinidad.

Captain R. G. STICKLAND has returned from Hong Kong.

Mr. L. J. WILMOTH has left for Burma.

The Secretary will be glad to receive information as to the whereabouts of the following members:—J. M. BAILEY, J. C. FORTUNE, D. H. GWINNER, L. B. HOLLOWAY, K. C. JOHNSON, I. C. LOW, L. R. PHILLIPS, J. K. WALTON, and W. WALLACE WATT.

The suggestion has been made that complete bound sets of the Journal should be available for sale to members of the Institution. Any member wishing to avail himself of this opportunity should communicate with the Secretary.

DECENNIAL INDEX, 1914 to 1924.

The complete index to the first ten volumes of the Journal of the Institution contains some 10,000 references to subjects and localities.

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THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

THE ONE HUNDRED AND FOURTEENTH GENERAL MEETING of The Institution of Petroleum Technologists was held at the House of the Royal Society of Arts, John Street, Adelphi, London, W.C., on Tuesday evening, 13th November, 1928, Mr. Alfred C. Adams, President, occupying the Chair.

The Secretary read the following list of members elected since the last meeting.

Members.—Ernest Cordingley Brewster, Jules Decat, Lewis McLauchlin Drader, Edward Franklin Evans, Thomas Nicol, Charles Archibald Philip Southwell, Emil Triandafil, Nicholas Ord Watson.

Associate Members.—Ernest Alexander Howard, Reginald Crawford Parker, Samuel Taylor Rogers, Horace Stephen Virgo, Bartholomew L. Voskuil.

Transference to Associate Member.—Galfrid Clement Keyworth Dunsterville, Anthony Gordon Englebach, Robert Desmond Forrester, John Berridge Kay, Thomas George Kidd, Robert Meyer Sturt Owen, Donald Simmons.

Students.—Clifford Henry George Hands, Walter Kohring, Henry Samuel Rogers.

Associate.—John Wardlaw Reid.

The Secretary reminded the members that nominations for the Council should be in the hands of the Secretary not later than January 31 next.

The following paper was read :—

Drilling and Production Methods in the Greater Seminole Field, Oklahoma, U.S.A.

By G. HESELDIN, M.Sc., Assoc.M.Inst.C.E. (Associate Member).

INTRODUCTION.

THE Greater Seminole Field is made up of five separate pools, namely, the Searight, Seminole City, Bowlegs and Little River pools in Seminole County and the Earlsboro pool (Fig. 1) in both Seminole and Pottawatomie Counties, Oklahoma.

The field has produced some 200,000,000 barrels of oil up to the end of June, 1928.

The gravity of the oil varies between 37° and 42° Baumé, the average being about 40°

The main producing horizon is the Wilcox Sand, which is found at a depth of from about 4,000 ft. to 4,300 ft. The Wilcox Sand is a fairly uniform fine grained sandstone —Ordovician in age.

A few of the wells produce from the Hunton Lime which is found at a depth of from 3,800 ft. to 4,200 ft. The Hunton Lime is not found in all wells, it is more prominent in the Searight pool than in the others. The Hunton Lime is a dark grey limestone which is found above the Wilcox Sand, it is of Siluro Devonian age. The oil in the Hunton Formation is of a somewhat lower gravity than the oil produced from the Wilcox Sand.

Drilling Methods.

General.—The total depth of the wells ranges from 4,000 ft. to 4,400 ft. depending on the location.

Nearly all the wells have been drilled down to 3,700 or 3,800 ft. with rotary tools, at which point a string of $8\frac{1}{4}$ in. casing is set and cemented. No water sands are encountered below this depth until the pay sand has been passed.

Drilling is continued with standard tools and when the Viola Lime is reached a string of $6\frac{5}{8}$ in. casing is set on top of the lime. The Viola Lime rests directly on top of the Wilcox Sand. This casing string is not cemented as it makes a good formation shut off with the lime. The well is continued through the lime and into the Wilcox sand with 5 in. tools.

Should trouble be encountered in the drilling, it is sometimes necessary to set the casing strings before the required depths are reached. Under these circumstances a string of $5\frac{3}{16}$ in. casing is set on top of the lime.

Standard tools are used for completing the wells owing to the depth and the comparatively low gas pressure of the sand.

With a few exceptions all the rotary drilling is done by drilling contractors. In most cases the contractors agree to complete the well down to the Wilcox Sand, but sometimes the operating companies put on their own standard tools and drill the standard tool portion of the hole themselves.

It is the general opinion that the drilling contractor puts the hole down quicker, surer, and also cheaper than the companies can do it.

Some of the drilling contractors are very successful, one of the largest firms of contractors in the field operates fourteen strings of tools and have their own private aeroplane.

The drilling crews work twelve hour towers and seven days a week.

The log of a well on which the writer worked might be of interest :—

Rig commenced : January 8, 1928.
Rig completed : January 11, 1928.

Drilling commenced : January 16, 1928.
Drilling completed : May 2, 1928.

Completed rotary portion of hole down to 4100 ft. and set the 8¼ in. casing on March 5 (*i.e.*, 50 days).

Rotary Drilling Speeds.

Greatest footage obtained per tower, 220 ft.
Least footage obtained per tower, 15 ft.
Average footage, 81·25 ft. per day, including setting and cementing surface pipe.
Ran core barrel three times. Lost one day on account of boiler blowing up.

Casing.

20 ft.—15½ in. 70 lb. casing, cemented with 45 sacks cement.
4096 ft.— 8¼ in. 32 lb. casing, 385 sacks cement and 50 gals. Master Kem.
4300 ft.— 6⅝ in. 24 lb. casing.
Ran collar buster at 4129, pulled out 6⅝ in. pipe, leaving 171 ft. of liner in hole.

Formations.

Woodford shale	4097 ft. to 4110 ft.	
Misener Sand	4110 ft. to 4114 ft.	Some oil and gas.
Hunton lime	4114 ft. to 4187 ft.	2500 ft. of oil in hole gas.
Sylvan shale	4187 ft. to 4294 ft.	
Viola lime	4294 ft. to 4330 ft.	Corrected to 4341 ft.
Brown sandy lime	4341 ft. to 4447 ft.	
Simpson sand	4447 ft. to 4478 ft.	400 ft. of water in hole.
Wilcox sand	4478 ft. to 4485 ft.	3000 ft. of water in hole.

Hole plugged back to 4397 ft.

The bottom water was shut off with lead and cement plugs.

The well now makes a flow of about 150 bbls. every two days through the 8¼ in. casing, it was a semi-wildcat well several miles from the main producing area and was, of course, a failure, as oil was expected in the Wilcox Sand.

Rotary Drilling.

Operation.—A cellar 10 ft. square and 10 ft. deep is used and the hole spudded with a 20 in. or 18 in. fishtail or disc bit.

The 20 in. hole is carried down to the first hard shell, at which point 15½ in. casing is set as a conductor, sometimes 12½ in. is used instead of the 15½ in. casing. The length of the conductor string or surface pipe, as it is called, varies in different parts of the field and ranges from 20 ft. to 100 ft. in depth.

Some contractors use a large rock bit to set their surface pipe, to enable them to drill through any hard shell that is encountered near the surface, and so set sufficient pipe to secure a good shut off.

At Little River the surface pipe is often set as deep as 300 ft. in order to shut off the loose river sands.

The surface pipe is occasionally cemented by the two plug method but more often, if only a small amount of pipe is set, the cement is simply poured down the inside and the outside of the pipe. About 40 to 50 sacks of cement are used for a short conductor, the cement is mixed with shovels in a box on the derrick floor.

A re-agent is used to hasten the setting time of the cement.

During the time taken for the cement to set, the work of rigging up the tools is completed and the rat hole is dug. Two joints of 8¼ in. casing are used to case the rat hole.

About three days after the cementing of the surface string, drilling is resumed with an 11-in. bit.

A fish tail, disc, or K.P. bit is used down to around 1700 ft., using the rock bit to drill through the occasional hard shells that are encountered; below this depth the rock bit is used continuously. Some contractors do not use a fishtail bit at all, they use the rock bit throughout.

When the disc bit is run a Reed three or four point reamer is run above the bit to help to keep the hole straight. Without the help of the reamer the disc bit is apt to drill a crooked hole.

The K.P. bit is very popular and seems destined to replace the ordinary fishtail bit in rotary drilling. The K.P. bit is somewhat similar to an ordinary fishtail bit, but it has the advantage of having two renewable cutter blades and two renewable reamer blades. The cutter blades are ribbed at the back so that the blade remains reasonably sharp, even when an inch or two has been worn off. The renewable blades are not expensive, they are easy to change and are securely held in the body of the tool. The K.P. bit drills a straighter and truer hole than either the disc bit or fishtail bit.

Rock Bits.—The Hughes Simplex Rock bit gives good service and very little trouble apart from being more liable to hang u

in the hole than a fishtail bit. From 25 to 35 sets of cones are used on each well, depending on the hardness of the formations encountered and the experience of the driller. This gives an average of 30 sets of cones per well, and an average footage of 126 feet per set of cones. The least footage obtained with a set of cones is about 3 or 4 feet in hard shell and the maximum footage obtained is from 250 ft. to 300 ft. in fairly soft shales. About 5 to 6 sets of side reamers are used per well, which gives an average footage of about 650 feet per set.

Some contractors run their side reamers until they are completely worn down, but this is a mistake, as, unless the reamers are changed frequently and the hole kept up to gauge, an undue strain is thrown on a new set of cones, when running them into the hole, if the hole is out of gauge. As the cost of the side reamers is not excessive the best practice is to change them fairly frequently.

When drilling below 2,600 ft. the bit has a tendency to drag, and occasionally hangs up, when coming out of the hole. In view of this an endeavour is made to keep the number of round trips made with the drill pipe as few as possible, and the driller tries to get as much footage as he can with a set of cones before pulling out. Sometimes the bit is pulled out and the cones are not worn sufficiently to be discarded; if the hole is shallow the cones are used again, but if the hole is deep new cones are put on and the partially worn set is saved to be used on the shallow portion of another hole.

The bit is kept on bottom for about 24 hours and the lubricator is adjusted for this time.

The successful operation of the rock bit depends on the proper lubrication of the cones. Great pains are taken to see that the oil ducts in the bits are clean and open and that the cones revolve perfectly freely before the bit is lowered into the hole, otherwise they are apt to stick and not rotate when they get on bottom.

Slush Pumps.—The secret of successful drilling with the rock bit, using the self cleaning type cones, seems to be in having a large volume of circulating fluid to thoroughly clean off the cones and prevent the bit from balling up. As a result, the tendency is for larger and yet larger pumps.

The majority of the pumps used have been of the 14 in. $\times 7\frac{1}{4}$ in. $\times 14$ in. size, but practically all the contractors have now replaced these pumps by larger ones. These larger pumps have a steam cylinder 14 in. to $14\frac{1}{2}$ in. in dia., a fluid end cylinder 7 in. to $7\frac{1}{2}$ in. dia., and a stroke of 18 in. to 20 in. depending on the maker. The pumps are built suitable for a steam pressure up to 250 lbs./sq. in. and a pump pressure of 1000 lb./sq. in., the water ends are tested up to a pressure of 1500 lbs./sq. in. at the factory

The longer stroke of these big pumps permits of a slower piston speed for the same volume of circulation, so that the wear and tear on the pumps is much less.

Steam piston valves are fitted instead of the slide valves usually employed.

The two slush pumps are set on ground level as near to the fluid level in the slush pit as is possible, in order to reduce the suction head.

The pump suction pipes are eight inches in diameter and are not fitted with a foot valve or strainer of any sort. The joints in the suction line are usually welded in order to prevent air leaks. The large pumps are often fitted with a special gasket, somewhat similar to an expansion joint, at the suction inlet to the fluid end. This enables the suction pipe to be raised and lowered in the slush pit at will, without loss of vacuum in the suction due to a loose joint.

There is a gate valve on the discharge line from each pump and another gate valve on the common line leading to the stand pipe. The stand pipe is usually placed in the left hand corner of the derrick as one faces the pumps.

The latest practice is to fit a Brauer Automatic Manifold Valve instead of the separate gate valve on each discharge line (Fig. 2). This apparatus consists of a cylinder about eighteen inches long and four inches in diameter. The discharge from one pump enters at one end of the cylinder and the discharge from the other pump enters at the opposite end. The cylinder contains a loose piston about four inches long fitted with rubber packing rings. The discharge from the cylinder is placed in the centre of the stroke of the piston. When a pump is started up it pushes the piston to one end of the cylinder and the fluid passes out of the central discharge and into the stand pipe. Should it be necessary to change pumps when the bit is on bottom the first pump is slowed down a little and the second pump opened up. As the pressure of the second pump is now greater than the first, the piston is pushed across to the opposite end of the cylinder and the discharge of the second pump is allowed to pass through to the stand pipe. This Automatic Valve allows the changing over from one pump to another with practically no interruption to the circulation, and with no hammering or racing of the pumps.

On some rigs the suctions of the two pumps are connected up so that the pumps can be compounded if desired, and the pressure increased. This high pressure is often required to recover circulation when the bit hangs up in the hole.

Owing to the rather imperfect arrangements for settling out the cuttings from the mud fluid, a fairly large proportion of these

cuttings are often drawn through the pumps. This quickly cuts out the working parts of the fluid end. Two sets of liners, two sets of fluid end piston rods, two sets of pistons and followers, ten sets of plunger packings and four to six sets of valve inserts are used per well. A set of valve seats lasts from two to three wells. The drilling of a well can be taken as a month's continuous operation of the pump.

The slush pumps are operated with their steam throttles wide open, and the noise of the pump exhaust is such as to make rotary drilling unpopular with the occupants of houses adjacent to a drilling well.

Drill Pipe.—Six inch, 22.2 lb. seamless steel drill pipe is used throughout.

Roughly about one-half the pipe used is of the regular length and is run in fourbles with a tool joint to every double. The other half is the long, 30 ft. joint style, this pipe has a tool joint to every single and is run in tribles of approximately 90 ft. A 38 ft. Kelly is used with this class of pipe.

The drill pipe is made up with a spinning rope, no tongs are used when running into the hole, except occasionally when the spinning rope fails to make up a joint properly. The pipe is rotated out of the hole. A good crew can run or pull a fourble at an average speed of one a minute (90 ft.).

A float valve is placed in the pipe.

Boilers.—Three 100 H.P. locomotive type boilers, placed as near to the rig as is conveniently possible, have been the rule. Although these boilers were only intended to carry a steam pressure of 175 lbs./sq. in. they were operated at 225 lbs./sq. in.

Recently, however, a larger and stronger boiler has been introduced. This boiler is rated at 110 horse power with a working pressure of 250 lbs./sq. in.

The practice of heating the feed water, with the exhaust steam from the engine, is spreading.

Equipment.—All makes of rotary equipment are used and there is a continuous improvement in equipment. The latest rigs are equipped with a 12 in. by 12 in. totally enclosed, ball bearing, twin cylinder engine with piston valves. A steam separator and trap is fitted on the steam inlet line. Roller bearing draw-works with steel posts are used. The rigs are equipped with 66 in. quadruple travelling blocks and $1\frac{1}{8}$ in. rotary lines.

Automatic catheads are on almost every rig.

There are one or two Haliburton Drilling Controls, and one Oilwell-Hild differential drive rig; apart from these, all the rotaries are hand fed.

A Martin-Loomis load indicator is now fitted to practically every rig. The indicator records the load on the bit on a dial in full view of the driller, and at the same time records the load on a twenty-four hour chart.

These charts are a good check on the drilling, as they record the load on the bit at all times, when a round trip was made, when the pipe was spudded, and so forth.

Mud Fluid.—The hole is started with clean water and the mud fluid is made by the bit as it drills through clay and soft shale beds. A sufficient quantity of good mud is usually made by the time the drill reaches a depth of 2,000 ft.

The mud is never weighed to test the specific gravity, the driller uses his own judgment as to its correct state.

The standing properties of the mud fluid are very good, there is only a negligible settlement in the first twenty-four hours.

Below 2,600 ft. there are several horizons that take up considerable quantities of mud and the driller often finds himself running short of mud by the time the hole is completed.

When the mud becomes too thin, hydrated lime is added to thicken it.

Drilling Speed.—If no unforeseen circumstances arise it takes about 30 to 35 days to put down one of these 3,700 ft. to 3,800 ft. rotary holes beginning with the 11 in. hole below the surface pipe. I think the record for the field was 3,780 ft. in 20 days.

Trouble is never very far away and skidded rigs are not uncommon. The chief trouble is the hanging up of the bit when coming out of the hole.

Crooked Hole.—The rotary tools have drilled very many crooked holes, hence the insistence of the operating companies on the use of load indicators.

Deflections taken with hydroflouric acid in glass bottles, run in a special holder on the end of a sand pump, are given.

Deflection taken at	Well A.	Well B.	Well C.	Well D.
500 ft.			0°.	
1000 ft.	2°.	8°.	2°.	0°
1500 ft.	5°.	19°.	2°.	
2000 ft.	11°.	25°.	2°.	11°
2500 ft.	16°.	22°.	2°.	
3000 ft.	12°.		4°.	
3500 ft.	10°.	(3525 ft.) 11°.	6°.	14°
4000 ft.	8°.		5°.	7°

Well A was the well whose log was given earlier in the paper. Well B was found to be impossible to pump.

FIG. 1.

GENERAL VIEW OF THE EARLSBORO POOL. NOTE THE 80,000 BARREL STORAGE TANKS IN COURSE OF ERECTION.

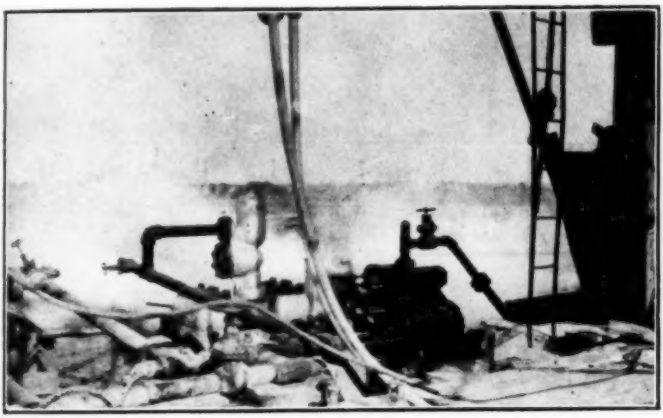

FIG. 2.

ONE OF THE LARGE SLUSH PUMPS IN ACTION. THE BRAUER AUTOMATIC MANIFOLD VALVE CAN BE SEEN IN THE FOREGROUND.

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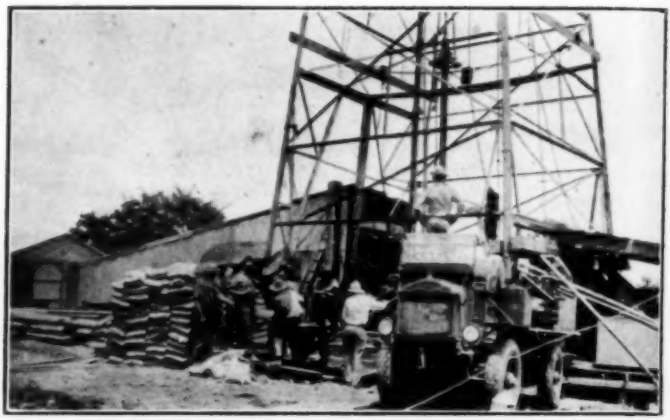

FIG. 3.

ALL READY TO CEMENT A STRING OF 8¼ IN. PIPE WITH THE HALLIBURTON CEMENTING OUTFIT. THE MIXER CAN BE SEEN BETWEEN THE TRUCK AND THE CEMENT BAGS.

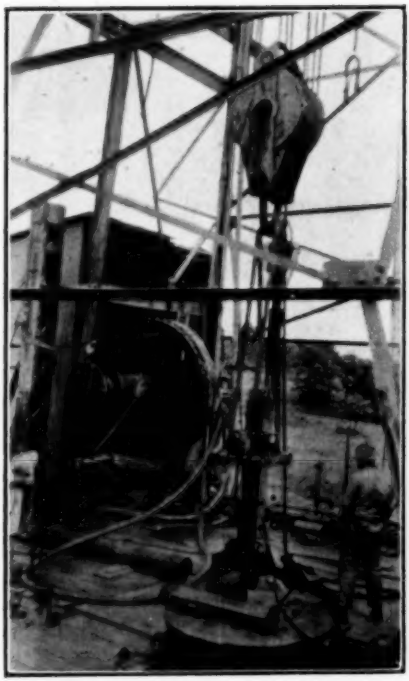

FIG. 4.

SETTING A 3805 FT. STRING OF 8¼ IN. 32 LBS. SEAMLESS CASING. THE CEMENTING PLUG CAN BE SEEN ON THE ROTARY TABLE IN THE FOREGROUND.

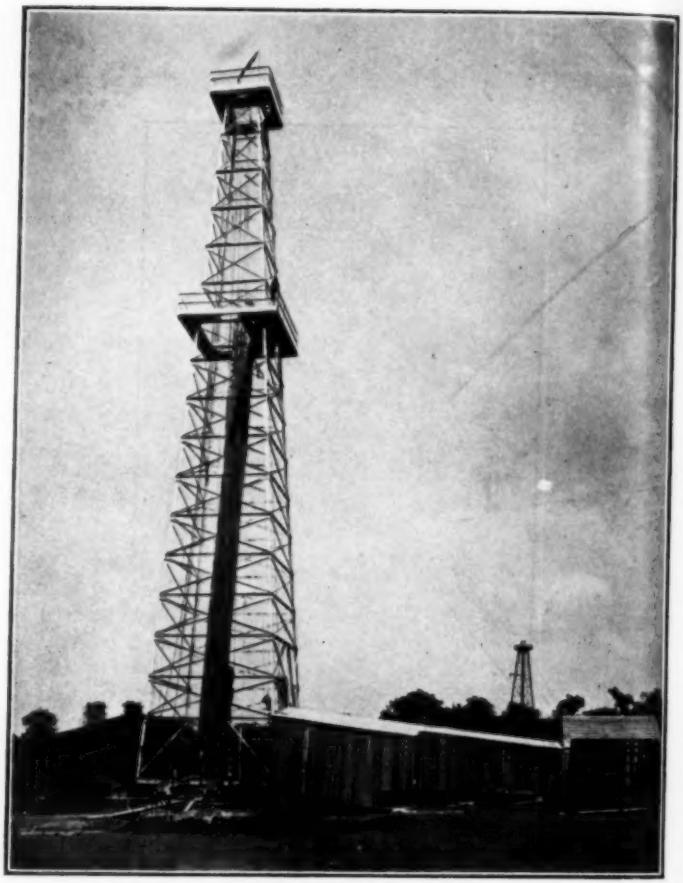

FIG. 5.

122 FT. GALVANISED ANGLE-IRON DERRICK. A TURN-BUCKLE DERRICK CAN CAN BE SEEN IN THE DISTANCE.

Wells A B C were drilled with hand-fed rotaries, without load indicators. Well D was drilled with an Oilwell-Hild differential drive rotary.

There was more than one instance in the field where the bit from one rig ran into the drill pipe of an offsetting well, 660 ft. away.

Standard Tool Drilling.

As previously mentioned, standard tools are employed to do the drilling from around 3,800 ft. down to the sand.

The drilling is generally good, especially the shale formations where 70 ft. to 80 ft. a tower can be made. Trouble is sometimes caused by the crookedness of the rotary hole.

If oil is encountered in the Misener sand or Hunton lime, difficulty is encountered in drilling the Sylvan shale, as the oil causes the shale to slump off into the hole. Under these conditions it is nearly always necessary to run the 6⅝ ft. casing and underream it through the shale.

The hard limestone which is often streaky causes a number of broken pins on the tool joints.

The rotary mud is bailed out of the 8¼ in. pipe with the drilling line, a 90 ft. bailer made up of joints of 6⅝ ft. pipe is used. Sometimes a set of long stroke jars are run on top of the bailer so that the bailer can be jarred loose if it should hang up in the hole.

The temper screw is never used except on fishing operations. The drilling line is slipped through the clamps when it is necessary to let out more line. This is rather hard on the lines, but is is a great time saver, and the line will wear out just as rapidly at the bottom as it will at the top.

Steel bull wheels, band wheels and calf wheels are used, but wooden Sampson posts and walking beams are common. Chain-driven sand reels are in general use.

The wells are usually drilled with steam ; an occasional well, however, has been drilled with electricity.

Casing.

The usual casing programme is :—

20 to 200 ft. of 12½ in. or 15½ in. surface pipe.
3600 to 3800 ft. of 8¼ in. 32 lb. seamless casing.
4000 to 4400 ft. of 6⅝ in. 24 lb. or 26 lb. seamless casing.

A few wells have been drilled recently with the following casing :—

20 to 200 ft. of 12½ in. or 15½ in. surface pipe.
4000 to 4400 ft. of 6⅝ in. 26 lb. casing.

If trouble has been encountered when drilling, or oil has been obtained in the Hunton lime or Misener sand, a liner of 5⅜ in. casing is often set.

Only seamless pipe is used (except for the surface pipe); some of the pipe is 8 thread, the remainder 10 thread.

An augmented rotary crew run the 8¼ in. string and a special casing crew run the 6⅝ in. pipe.

A Bovaird spider is generally used, also Butler or Bovaird elevators; these elevators hold the pipe in slips and do not bear on the collar. An ordinary gate elevator is used on the first 1000 ft. or so of pipe in order to save time.

A spinning rope is generally used for making up the joints initially, although there are a few companies that insist on the crews using a pole and screwing up the joints by hand. The use of the pole ensures that the joints are properly screwed together before the tongs are put on, and eliminates the danger of burning the threads.

Companies that have large stocks of used pipe on hand run from 1000 ft. to 2000 ft. of old pipe on the bottom of a string, employing new pipe for the upper portion. It has been proved by experience that it is false economy to use any but first-class pipe on these deep wells.

The joints of pipe are carefully cleaned, inspected and measured just prior to running. This work is usually in charge of a special pipe man whose sole job it is to go from one location to another inspecting and tallying pipe. Any pipe that is not in first-class condition is thrown out.

A rotary crew can set about 3700 ft. of 8¼ in. casing in from 10 to 16 hours and a casing crew on standard tools can set around 4100 ft. of 6⅝ in. in from 18 to 24 hours.

After a string of casing has been set, the casing is cut off in the cellar with a hack saw and threaded by hand with a set of stocks and dies.

Cementing.

The 8¼ in. casing string is always cemented. 350 to 500 sacks (1 sack=94 lb.) of a good brand of Portland cement are used, and the cement is mixed with about 5 or 6 gals. of water per sack.

As an 11 in. hole is drilled for the 8¼ in. pipe, the casing is therefore cemented for a distance of some 1500 ft. to 2000 ft. above the casing shoe.

From 50 to 150 gals. of accelerator are used, either the straight liquid calcium chloride or one of the propriety brands.

There is no doubt but that an excessive amount of accelerator is used in most cases, which only weakens the strength of the cement, and does not increase the setting time.

The casing is run with a guide shoe, and a float valve is placed in the casing usually two joints above the shoe. This prohibits the use of the two plug method of cementing.

The casing is held off bottom a sufficient distance to enable a fairly good circulation to be obtained, the casing is circulated for a short time prior to commencing cementing operations to ensure that it is quite free.

The casing depth is obtained from an accurate drill pipe and casing tally; if the pipe hangs up and will not go to bottom, it is cemented at the last point where circulation can be obtained.

Cementing contractors do the cementing work, which includes the provision of the cement mixer and pumps and a tank for clear water, hose from the pumps to the well, connections to the well casing and a couple of men to supervise the work and operate the pumps. The pumps and tank are mounted on a truck. The operating companies lay water lines and steam lines and connect them up to the truck, provide the cement and accelerator and the labour for dumping the cement into the mixer.

The price for cementing a string of 8¼ in. casing is $250.00 net.

Two major systems of cementing wells are used, one the plug method and the other the displacement method. The plug method is the most popular and will be described first. (Figs. 3 and 4).

Plug Method.—The cement bags are stacked around the mixer, which is placed some 10 ft. or 12 ft. away from the truck, a table with a knife blade fitted in the middle is set up level with the top of the mixer hopper. The sacks which are usually made of a number of layers of brown paper are slit open by the knife as they are slid along the table, and the cement falls directly into the hopper.

A nozzle is fitted at the bottom of the hopper and a jet of water mixes the cement and draws it down the hopper. The liquid cement from the hopper is discharged into a suction box, where it is picked up by one of the pumps and pumped down the casing.

Two pumps are mounted on the truck, one a 10 in. × 3½ in. × 10 in. for handling the clear water to the mixer, and the other a 10 in. × 4½ in. × 10 in. pump, which handles the cement.

When mixing the cement the clear water pump which supplies the water to the mixer nozzle operates at a pressure of between 500 and 600 lb. per sq. in. The pumps are regulated so that they work together, that is, the cement pump pumps out the liquid cement just as fast as the clear water pump makes it.

Usually the accelerator is placed in the suction box of the cement pump and does not therefore have a very good chance of being intimately mixed with the liquid cement. A few of the companies insist that the accelerator be poured into the mixing water tank, to ensure that the accelerator is more thoroughly distributed throughout the mass of liquid cement. The proportion of accelerator is usually increased for the last 50 to 100 sacks of cement

to insure a quick set around the shoe and lower portion of the pipe.

When all the cement has been pumped into the casing, the casing connections are taken off and a wooden plug fitted with a leather cup and gasket is pushed into the pipe. A special connection is then screwed on the top of the casing which permits a weight attached to the end of a coil of piano wire to run down inside the casing and measure the depth of the plug at any moment.

The rotary slush pumps are used for pumping down the plug.

A well-measuring device is used for recording the depth of the plug. The wire passes round a pulley and an automatic counter records the depth, a "pick up" of the weight on the plug must be obtained to get the correct depth.

The measuring device is clamped on to the draw works post near the brake.

When the plug has reached a pre-determined depth, the slush pumps are shut off and the measuring line spooled out of the hole, a check on the accuracy of the measurement is obtained by noting if the zero reading coincides with the same point as that used when the line was first run in.

After the measuring line weight has been pulled up the valve on top of the casing swege is closed so as to keep the pressure on the cement.

Here is a log of an actual cementing job to illustrate the time taken for the various operations. This is about an average job:—

Depth of hole 3905 ft.	8¼ in. 32 lb. 8thd. seamless pipe
400 sacks of cement	80 gall. calcium chloride
Fairly good circulation	
Started mixing 1.10 p.m.	One of the tees between clear water water pump and mixer sprang a leak, had to slow down pump for last 100 sacks.
Finished „ 1.30 p.m.	
Started pumping down plug 1.40 p.m.	
Plug pumped to bottom (3830 ft.) 2.00 p.m.	
Total time taken for cement job 50 min.	

First caught plug at 640 ft, lost it at 3100 ft. but found it again at 3200 ft. Slush pump began to labour at 3500 ft. but eased up towards the end. 75 ft. of cement left inside pipe.

It is usual to leave from 50 to 100 feet of cement in the pipe to ensure that only clean cement is left around the shoe. Should the mud fluid leak past the plug, the last few feet of cement would be contaminated, with a resultant loss in strength.

The above system is employed by the Halliburton Oil Well Cementing Company, and is a patented process. The mixer they use is probably the fastest method of mixing cement yet devised.

Displacement Method.—The second method of cementing is called the Displacement System, and has been used quite extensively.

In this system the mixer is attached to the truck, and consists of a set of paddles driven from the truck motor. Here again one of the pumps on the truck supplies the mixing water, and the other pumps the cement down the hole.

The water tank in this instance, however, is divided into two equal halves, each part having a capacity of 112 cub. ft.

When all the cement has been mixed and pumped into the casing the pump suction is switched into the water tank and the water is pumped in on top of the cement. After the original tanks of water have been pumped out mud fluid is turned into the tank, and is pumped into the casing. A careful check is made on the volume of the fluid pumped into the pipe, so that only the correct amount necessary to displace the cement down the hole and up around the outside of the pipe is used. As one-half of the tank is being emptied the other half is being filled, so that the pumping-down process is continuous.

The reason for pumping down a complete tank of clear water on the top of the cement is to wash the cement off the walls of the pipe and prevent contamination with mud fluid.

Although the cement mixer in the displacement method is slower than the Halliburton mixer, the time taken on a cementing job is roughly the same, due to the fact that the connections on top of the casing have not to be changed when using the displacement method.

It would appear that excessive contamination between the cement and the mud fluid was bound to take place, yet the cement is always found at or very near to the predetermined depth when the tools are run in after the well has been opened up.

A third method of cementing employing a floating ball valve between the cement and the mud fluid, and a seat for the ball near the bottom of the pipe, has been used to a very limited extent but is sufficiently novel to be worth mentioning.

The ball is made up of a substance whose specific gravity is less than that of liquid cement, yet greater than that of mud fluid. With a result that it will float in cement and sink in mud. A seat for the ball is placed in the pipe at the point at which it is desired to leave the top of the cement. The ball reaches the seat when all the cement has been pumped out, and by so doing causes the pump to stall, indicating that the cement has been pumped down.

The ball is a very loose fit in the casing.

Derricks.

Drilling derricks.—The usual size of drilling derrick is the 122 ft. combination derrick, with a 24-ft. base and a 5 ft. 6 in. water table opening. (Fig. 5.)

The all-steel derrick is probably the most popular rig, but there are a very large number of turnbuckle derricks and also a few wooden ones.

The turnbuckle derrick is very common in the mid-Continent field. The derrick legs are usually composed of 10 in by 10 in. square timbers, the girts are made of steel pipe and the braces from iron rods fitted with a turnbuckle to enable the correct tension to be placed on them. On one type of turnbuckle derrick the girts consist of boards as in the wooden rig, but the braces are made from iron bars. The turnbuckle rig has the "give" of a wooden rig, but has a much smaller wind resistance and depreciates much less when it is moved from one location to another.

The first cost of a turnbuckle rig is less than that of a steel rig.

The galvanised angle-iron derrick is the most popular steel rig, although there are a large number of steel tubular derricks.

The starting legs in the angle-iron derrick are usually 6 in. × 6 in. × $\frac{5}{8}$ in. angles, and the running legs 6 in. × 6 in. × $\frac{1}{2}$ in. angles. A heavier derrick has been recently introduced having 6 in. × 6 in. × $\frac{3}{4}$ in. angles for starting legs and 6 in. × 6 in. × $\frac{5}{8}$ in. angles for the running legs. The second and third legs are of the same size as the starting legs.

The weight of the former derrick is 33,070 lb. with a safe working load (A.P.I. rating) of 323,000 lb. The weight of the new type derrick is 35,320 lb. with a safe working load of 369,000 lb.

These derricks are provided with a crow's nest and a working platform at the fourbles board.

The derrick sills usually consist of 8 in. × 10 in. timbers, steel sills are seldom used.

The steel rigs are set on concrete foundation blocks and the wooden rigs on timber cribbing.

It takes about four to five days to erect a steel derrick including the placing of the concrete in the foundation blocks. A wooden rig can be built in three days.

Pumping derrick.—Some of the operators leave the drilling derricks standing and use it as a production derrick after the well comes in; others pull down the drilling derrick, and erect a pumping or stubb derrick for production purposes.

When the labour and material charges for pulling down the drilling derrick and putting up the pumping derrick are considered, and also the fact that it is impossible to get at the well should it

"go dead" whilst the change of derricks is in progress, there is very little economy effected by putting in pumping derricks.

Well Connections.

A bradenhead is fitted between the 6⅝ in. and 8¼ in. casing strings.

If the Hunton lime has been encountered, the bradenhead is connected to the lead line with a check valve on the line and the gas and oil, if any, is recovered from this formation.

Sometimes a master gate valve is fitted on the 6⅝ in. casing, but more usually this is omitted and a 6⅝-in. high pressure tee screws directly on top of the casing. A nipple screws in the top of the tee and on to the nipple is screwed a control head.

A 6⅝-in. lead line is screwed into the high-pressure tee and runs horizontally out under the derrick floor. As this line emerges from under the floor, connections for the following appliances are welded in place:—

1. Pressure gauge.
2. Thermometer.
3. Connection for drawing off oil samples.
4. Connection for applying Tret-o-Lite to the oil.

The lead line usually passes out on the bull wheel side of the derrick, as the gas trap is generally placed on this side.

The riser pipe to the gas trap is welded on to the lead line at an angle of from 30° to 60° to the vertical in order to reduce pipe friction between the well and the trap. It has been found that there is a distinct gain in production if abrupt turns and changes in direction are avoided between the well head and the trap. Eddying action, set up by abrupt changes in direction, breaks up the oil slug, thus permitting gas to blow through, and allowing some of the oil to fall back down the hole until it is caught by another slug of oil which is coming up. Some operators use a special teepiece on the well head, the outlet branch being in the form of a bend with a long easy radius

A gate valve is placed at the lower end of the riser pipe and a dresser sleeve coupling connects the riser pipe to the trap connections.

A teepiece is screwed on the end of the lead line and a half swing and a gate connects this line with the bleeder pipe which empties into the slush pit. The bleeder enables the well to be opened to atmospheric pressure and allows the oil and gas to escape when work is being done on the trap or any of the connections.

Sometimes an additional short piece of pipe with a gate at the end is welded at an angle to the lead line. This extra connection

is put on to enable another trap to be connected up should something go wrong with the original trap, or if the production is too large for the first trap to handle.

Whilst on the subject of well connections, it seems opportune to emphasise the great extent to which the oxy-acetylene and electric welding appliances are used in connection work, and the great economies that are effected by their use.

The electric welding outfit is generally housed in the shop, but a portable oxy-acetylene unit is hauled about the lease on skids. A portable acetylene generator is used in preference to the bottled gas, as it is considerably cheaper to run if a fair amount of welding work has to be done.

Oil and Gas Separator or Trap.

Instead of having one oil and gas separator, or trap as it is usually called, to serve a group of wells, which is the usual practice in other fields, a trap is connected up to each well. (Fig. 6).

The rock pressure in the Seminole field is low, as is also the gas oil ratio; the amount of back pressure held on each well has, therefore, a great bearing on its production and ultimate life, for a variation of even a few pounds in back pressure often has a considerable effect. A separate gas trap is therefore fitted to permit the correct regulation of the back pressure on each well.

Back pressures held on the traps vary from about 2 lb. per sq. in. to 25 lb. per sq. in., the average back pressure being about 12 lb. per sq. in.

The gas trap is placed at such a height that there is a free gravity fall from the trap to the stock tanks. In order to obtain this fall it is often necessary to place the trap above ground level, in some case as high as 25 feet. The traps are placed on either wood or steel platforms.

The size of the traps varies with the different makes and styles, but a popular size is 5 ft. diam. × 15 ft. high with a 125-lb. working pressure. This size of trap will handle a maximum of 6000 bbls. of oil and 20,000,000 c. ft. of gas per day. The oil and gas connections are 6⅝ in. and the trap weighs approximately 5,000 lb.

The oil line from the oil regulator on the trap is 6⅝ in., but a short distance from the trap the line branches into two 4-in. lines which run side by side to the stock tanks. The idea of the double line is that one line can be used whilst repairs are effected to the other line, also as the production of the well declines, one of the 4-in. lines can be taken up, the remaining line being quite adequate to handle all the production.

The gas line from the trap is also 6⅝ in. in diameter. An orifice meter is placed on this line to measure the amount of the natural gas coming from the well.

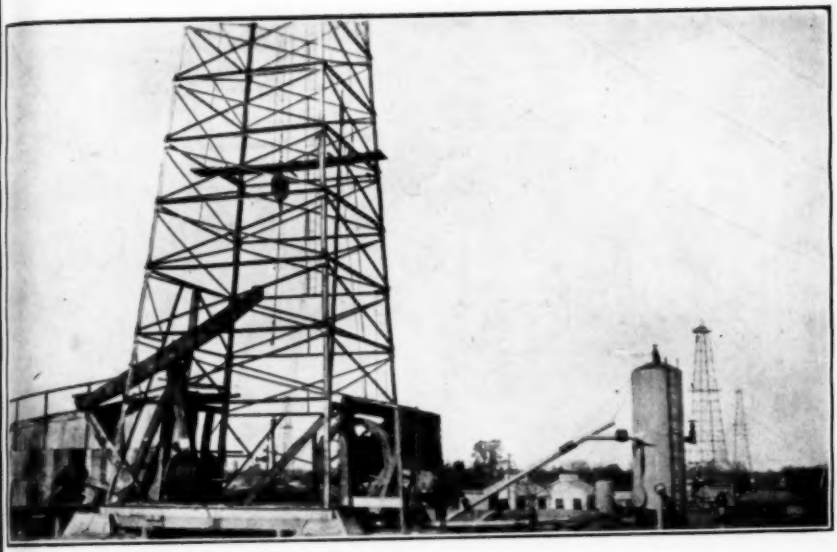

FIG. 6.

TRAP AND CONNECTIONS ON A WELL BEING PRODUCED BY THE GAS LIFT. THE COMPRESSOR STATION BUILDING CAN BE SEEN IN THE DISTANCE.

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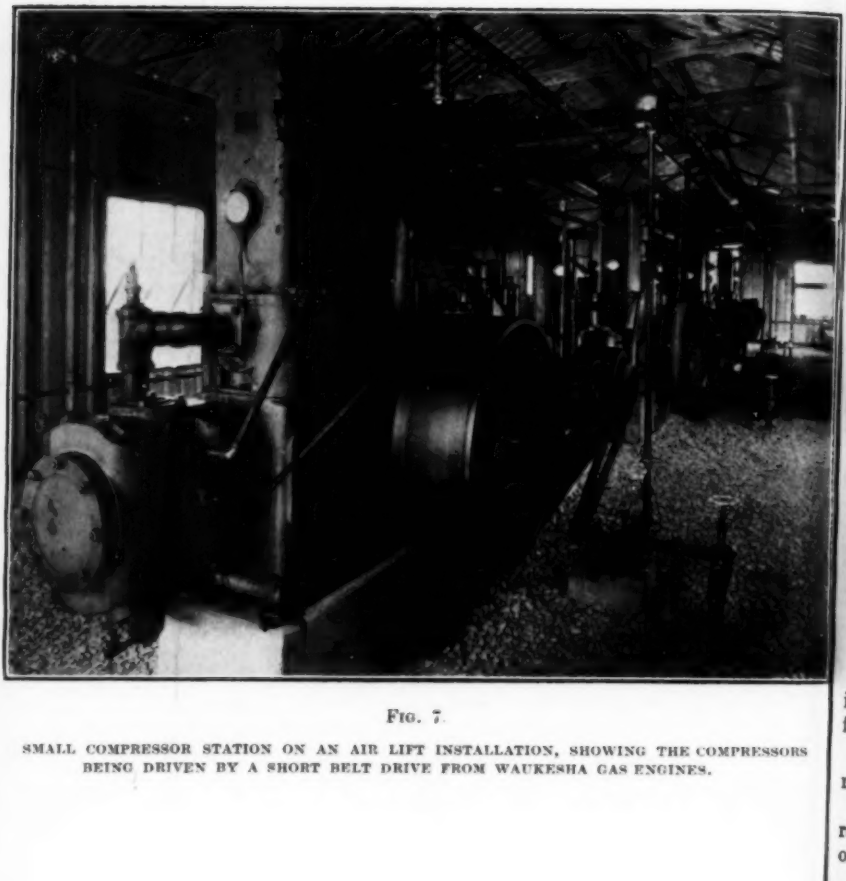

FIG. 7.

SMALL COMPRESSOR STATION ON AN AIR LIFT INSTALLATION, SHOWING THE COMPRESSORS BEING DRIVEN BY A SHORT BELT DRIVE FROM WAUKESHA GAS ENGINES.

Two risers or vent pipes about 20 ft. high are fitted to each trap, They are placed about 100 ft. to 200 ft. from the trap and a similar distance from each other. Both risers are connected to the gas line by horizontal lines which are buried (like all other lines that are laid at ground level). One riser is fitted with a regulating valve and also a gate valve, which is usually left open. The regulating valve is set for the predetermined back pressure. Should this pressure be exceeded, the regulating valve will open and allow the excess gas to escape out of the riser into the atmosphere. The second riser is put in primarily as a safety precaution. Should the gas escaping from the first riser catch fire the fire can be extinguished by opening the gate on the second riser and closing the gate on the first. The second riser also permits the gas pressure on the trap to be released, when necessary, without altering the adjustment of the regulating valve.

A 4 in. safety pop is fitted on the top of the trap to prevent undue pressures being placed on the trap. Sometimes the outlet from this safety valve is led off through a 3 in. or 4 in. line and allowed to escape through a riser placed some distance from the trap, but more usually the gas is allowed to blow off directly on top of the trap.

A trap is subject to the greatest strain when a well is being broken out with the air-gas lift. The sudden slug of oil and gas under high pressure is apt to damage a trap if it is not securely guyed down to the ground or if the regulating valve or relief valve sticks. A few traps have been blown up when breaking out big wells.

There are two types of traps in general use, the Smith Separator and the National Separator. They are a little different in construction, but both seem to perform their duties equally well.

Air-Gas Lift.

The air-gas lift system for producing oil has been used extensively in the Greater Seminole Field ; 55 per cent. of the total production from the field must be credited to it.

Air.—Whilst a few of the leases are flowed on the air lift the majority are on the gas lift.

When air is used for the lift the corrosion of the tubing is very rapid. Wrought iron tubing and special galvanized tubing is often used to arrest the rapid corrosion.

After performing its cycle in the well the air is caught in the trap along with what natural gas the well is making, and led off to some convenient place, where it is allowed to escape into the atmosphere from a vent pipe or riser.

Air is only used when gas is not available. Many wells that were flowed with air at the beginning were changed over to gas when gas became more plentiful.

Gas.—When gas is used for the lift the green or natural gas is sometimes recycled continuously from the well to the compressors and back again, any surplus gas being withdrawn from the system by means of a regulating valve.

More often, however, the residue gas from the gasoline plant is used to flow the well, all the gas coming from the wells going back to the gasoline plant, where the gasoline content is extracted before the gas is returned to the lease for recycling. This system enables the gasoline plants to make more gasoline, and although there is a tendency to reduce the gravity of the oil, it is almost negligible, and is more than offset by the increase in the gasoline manufacture.

As mentioned before, the gas oil ratio of a Wilcox sand well is low, and the wells do not make much gas. Some wells require more gas to flow them than is returned back from the well. This means that some of the gas is being driven back into the formation and probably has an outlet in an adjoining well.

Compressor Stations.—A compressor station is usually built to serve one lease and is placed somewhere near the centre, but where the same company has adjoining leases one compressor plant will be made to serve two or three small leases.

When the compressor station is a long way from a well there is a considerable pressure drop between the compressors and the well, so that the economy effected by having one centrally located plant, which can be run with minimum labour charges, is offset by the extra power required to overcome the pipe line friction.

To give an idea of the pressure drop that occurs between the compressors and the well a few examples are quoted from actual tests made on leases scattered throughout the field :—

Location.	Pressure at meter (compressor stn.).	Temp. °F.	Volume of gas. Cub. ft./24 hrs.	Sp. gr. of gas.	Length of line.	Pressure at well, lb./sq. in.	Pressure drop, lb./sq. in.
A	285	160	1150	1·05	1134 ft.	256	29
B	184	170	745	1·05	1556 ft.	160	24
C	190	198	985	1·05	489 ft.	169	21
D	242	174	1142	1·13	340 ft.	231	11

The diameter of the line in each case was 2 in.

The compressor stations (Fig. 7) consist of multiple units, which make the operation of the plant very flexible. The largest stations contain up to thirty machines, and the other extreme is represented by the small station of only two units, which flows a single well.

Two stage compressors with an intercooler are used, the most popular size having a 10 in. L.P. cylinder, a 4¼ in. H.P. cylinder and a 10 in. stroke. The 10 in.×6 in.×10 in. machine is also widely used.

Some of the machines are built on the tandem principle and others on the cross-compound (*i.e.*, each cylinder has a separate crosshead and connecting rod).

The 10 in.×4¼ in.×10 in. machines are built for a working pressure of 500 lb./sq. in., with a breaking out pressure of 1000 lb./ sq. in. The 10 in. × 6 in.×10 in. machine, while not intended by the makers, are often used for the same working pressures as the smaller machines.

Some of the compressors used in gas lift work are heavily overloaded, and as a result upkeep charges are often heavy. Tests on the power consumption of a gas lift station showed that some of the motors were overloaded as high as 30 per cent.

Prime Movers.—The power units employed to drive the compressors are either electric motors or gas engines. The latter are either the horizontal single cylinder machine or the vertical multiple cylinder, automobile type engine. A common example of the latter type of engine is the Waukesha.

The electric motor has the advantage over the gas engine of a cheaper initial cost and a great saving in upkeep charges. It is also much handier to move from place to place.

It has the disadvantage of being put out of action during electrical storms.

The gas engine has the advantage of having no power bill at the end of the month if the gas used in the engine is considered to be valueless; it is not affected by electrical storms.

Trouble is encountered in some parts of the field due to the bad qualities of the cooling water.

The electric motors operate on a three-phase current, 60 cycles, with a voltage of 2200; they are, therefore, small in size and easily handled. 75 h.-p. motors are used on the 10 in.×4¼ in.×10in. machines and 100 h.-p. on the 10 in.×6 in.×10 in. machines. Power is obtained from the supply company at, roughly, 1.25 cents per kw. hour.

A short belt drive with jockey pulley is used to transmit the power between the motor and compressor. The Texrope drive is now being introduced to replace the belt drive.

The belt drive is used when the Waukesha gas engine is employed as the power unit.

Headers.—The discharge from each machine passes through an arrangement of headers or manifold whereby any number or group of compressors can be made to flow any particular well.

The headers are often 4 in. dia. cast steel pipes connected together by 4 in. flanged cast steel gate valves. The hot gas is very detrimental to the valve seats and trouble is often caused by leaky gates.

The headers are usually placed in a separate house outside the compressor station building. Sometimes no building is put up at all, the headers are simply left in the open.

Intercoolers.—The intercoolers are often placed on the outside of the building.

Special intercoolers are sometimes used and the gasoline content taken from the green gas as it is cooled between stages. On one lease where ten compressors are running, about 2,300 gallons of highly volatile gasoline are made each day.

Temporary Installations.—Temporary installations of semi-portable units of compressors and automobile type gas engines, mounted on skids, are sometimes used. These temporary units are employed where a well is not expected to produce profitably on the gas lift for any length of time. They are also used to flow a well during the time taken to build the regular compressor station.

In the Seminole field the first ten or fifteen days' production of a well yields the most profit, and it often depends on the production of these first two weeks whether a well pays for itself or not.

It is, therefore, important that everything is ready to obtain the maximum production in these first two weeks. For this reason, a company will sometimes install an expensive compressor station on a lease whilst the wells are still drilling, so, that if they obtain production, they can put the wells immediately on the air-gas lift should it be found necessary to do so.

An angle type compressor belt driven from a Waukesha or similar engine, both mounted on skids, makes a convenient portable plant.

Tubing Arrangements.—The tubing arrangements consist of a single string of tubing run inside the oil string. The gas is usually admitted through the tubing, the oil and gas flowing up to the surface through the annular space between the tubing and the casing. As will be explained later, the directions of flow are sometimes reversed.

The tubing consists of the usual oil well tubing either the regular or upset pattern. Nearly all the tubing used is made of seamless steel although wrought iron and special coated tubing is occasionally used if trouble is being caused by corrosion.

The tubing is supported on the control head by a tubing supporter as on a pumping well, or more generally the tubing is held in a tubing oil saver, so that the oil saver is already in place when it becomes necessary to pull the tubing.

Tubing catchers are not generally used as they restrict the

passage of the oil and gas. Special tubing catchers have been designed for air lift work, and these are occasionally used.

Foot pieces of varied design were tried in the initial application of the air-gas lift, but they are now generally omitted, no device of any kind being placed on the end of the tubing.

The function of the foot piece is to utilise the kinetic energy of the gas and also to divide the gas up into small bubbles. On a shallow bore of large diameter a properly designed foot piece increases the efficiency of the lift, but on a deep well of restricted bore the effect of a foot piece (on the efficiency of the lift) is not noticeable. The finely divided gas bubbles will coalesce in any case long before they reach the surface and the work done by the kinetic energy of the gas is very small compared with the total work done in lifting the oil.

When a well is first put on the air-gas lift, the production is generally large and the area of the eduction pipe should be as large as possible to avoid restricting the passage of the oil and gas. For this reason 2 in.-4½ lb. plain tubing is used as the gas inlet pipe and the annular space between the 2 in. tubing and the 6⅝ in. casing as the eduction pipe.

As the volume of natural gas declines, more and more input gas is required to flow the well.

There will also be an increase in slippage, due to the comparatively large area of the eduction pipe, this again necessitating an increase in the gas input volume. The working pressure will gradually increase as the input gas volume is raised owing to the restricted area of the 2 in. tubing.

When the working pressure and input gas volume become too high, the 2 in. tubing is pulled out and 2½ in.-6.25 lbs. upset tubing is substituted. This increases the area of the gas inlet pipe and reduces the area of the eduction pipe.

The shutting down of a well whilst the tubing is being changed is often a risky proceeding, as wells have been known to go dead or take a big drop in production when they are shut down for the eight or nine hours necessary for the change.

As a well further declines, the direction of flow is reversed, that is, the annular space between the 2½ in. tubing and the 6⅝ in. casing becomes the gas inlet pipe and the 2½ in. tubing becomes the eduction pipe. This change reduces considerably the volume of input gas necessary to flow a well as it materially reduces the slippage.

An ideal method for flowing a well in its early stages, where a perforated string of 5$\frac{9}{16}$ in. casing has been set as the oil string, is to use the annular space between the 5$\frac{9}{16}$ in. and 6⅝ in. casings as the gas inlet pipe and the 5$\frac{9}{16}$ in. casing is the eduction pipe.

Tapered Tubing.—For maximum efficiency it is desirable that the velocity of the oil and gas in the eduction pipe remain constant during its passage from the bottom of the well to the surface. To achieve this object, a few companies employ what is called tapered or graduated tubing.

Tubing of a small diameter is placed at the bottom of the well the size increasing as it reaches the surface, the tubing in this case serving as the eduction pipe. Owing to the restriction imposed by the limited bore of the hole it is not possible to maintain a uniform velocity, but by using a string of tubing varying from 2 in. at the bottom to 5 $\frac{1}{16}$ in. at the top, the change in velocity is not nearly so great as if a straight sized tubing string were used.

The advantage of using tapered tubing is only apparent when the production of a well declines to around 400 bbls. a day and under, but there is one instance in the field where a well, having a production of 800 bbls. a day, is flowed through a tapered string.

The following data is given for two wells being flowed through tapered tubing.

EXAMPLES OF TAPERED TUBING STRINGS.

Well A.—Input gas volume—326,000 c. ft./24 hr.
Working Pressure—120 lb./sq. in.
Production 63 bbls./day ¼% B.S.

Tubing:	2″ —1,959 ft.	Total Depth of Well—4,210 ft.
	2½″—1,076 ft.	Top of 1st Wilcox —4,121 ft.
	3″ — 594 ft.	Top of 2nd Wilcox—4,204 ft.
	4″ — 492 ft.	
Total:	4,121 ft.	

Well B.—Input gas volume—518,000 c. ft./24 hrs.
Working Pressure—140 lb./sq. in.
Production—215 bbls./day.

Tubing:	2½″—1,977 ft.	Total Depth of Well—4,494 ft.
	3″ —1,124 ft.	Top of Wilcox Sand—4,492 ft.
	4″ — 848 ft.	
	5 $\frac{1}{16}$″— 506 ft.	
Total:	4,457 ft.	

Volumes and Pressures.—The pressure and volume necessary to flow a well varies in every case since hardly any two wells are alike. It is mainly a matter of experiment to determine the pressure and volume that will secure maximum production.

Generally speaking, the pressure and volume increase with the life of the well, due to the decline in natural gas, and they are considerably increased when water begins to show up in the well in appreciable quantities.

Working pressures range from 150 lb./sq. in. to 450 lb./sq. in., and volumes from 500,000 cu. ft. of gas per day to as high as 1,600,000 cu. ft. per day.

Some wells are very sensitive to change in volume ; even a small increase or decrease in volume will cause a falling off in production. In other cases, maximum production is obtained by making a change in the volume every day or two. If the volume remains steady for more than three days, the production will begin to decline, but a slight increase or decrease in the volume (it doesn't matter which) will bring back the well to its full production. Generally speaking, however, an increase in volume will raise the production.

The volume of the input gas going to each well is measured separately. An orifice meter is placed on the line as near to the compressor station as is conveniently possible. An orifice meter is also placed on the gas line leading from the gas trap. The reading on this second meter less the input volume gives the amount of natural gas being produced by the well.

As a back pressure of from 2 to 25 lb. is held on the gas traps, the compressor intake is usually above atmospheric pressure up to a maximum of about 20 lb./sq. in. This enables a higher pressure to be obtained by the compressor or a given pressure can be obtained with less load than if an atmospheric intake pressure were used.

A few examples of pressures that are carried on the different leases are given :—

Lease	Intake pressure. lb./sq. in.	Intercooler pressure. lb./sq. in.	Discharge pressure. lb./sq. in.
..	18—24	140—150	300—350
..	0	50	175
..	8	120	380

Some pressures and volumes on different wells are also given :—

Well.	Working Pressure. lb./sq. in.	Volume, M. cu. ft. per day.	Trap pressure, lb./sq. in.	Daily production in barrels. Oil.	Water.	Total Fluid.
A	275	1335	18	885	—	885
B	290 (average)	984	12	974	80	1854
C	300	1512	5	921	295	1216
D	185	867	3	323	20	343
E	280	1065	18	40	245	285

Well B is being flowed on the intermittent injection system, all the other wells are on straight flowing.

Well E flows through the tubing, all the others flow through the casing.

Intermittent Injection.—The intermittent injection of gas has been adopted extensively in gas lift installations with a fair measure of success.

Gas is introduced during periods of 2 to 10 minutes at a rate considerably greater than that required to obtain production with straight flowing, and is then cut off for intervals varying from 3 to 15 minutes. Two to five wells can be operated from the same group of compressors. The maximum working pressure is usually higher, but the average pressure is generally equal to, or in some cases less, than the working pressure required for straight flowing.

During the off period, when no gas is admitted, the oil accumulates in the eduction pipe, and when the gas is turned on it drives out the oil in a series of slugs. This is opposed to the theory that the finer the gas bubbles the more efficient will be the lift.

The gas is admitted to a well by means of a quick opening valve, operated by an electric timing device, or by an arrangement of a water tumbler or wobbler. The electric device is more easily adjusted than the other arrangements, but it is more expensive, and the operating mechanism on the valve is inclined to get out of order, due to corrosion by the hot gases, and the carboning up of the gas tubes.

The results obtained with intermittent injection are shown below. The table gives a comparison between intermittent injection and straight flowing, taken over a period of ten days on each system. The gain or loss for intermittent injection is shown by a plus or minus sign.

TABLE 1.

Summary of tests on intermittent injection and straight flowing. Gain or loss for intermittent injection on individual leases.

Lease.	Daily production Bbls. Oil.	Water.	Power consumption. kw. hr.	No. of compressors.	Size.	Gas inlet vol. M.cu. ft./day.
A	+79	+84·2	—57	—1	10in. × 12in. × 10in.	—2052
				—2	10in. × 4½in. × 10in.	
B	+56	+19	—96	—1	10in. × 4½in. × 10in.	—1405
C	0	+26·4	—138	—1	10in. × 4½in. × 10in.	— 799
				—1	10in. × 6in. × 10in.	

It will be seen that there is a saving in the number of compressors that are necessary to flow a lease, with a consequent saving of power, a reduction in the amount of input gas and a small increase in production.

The table below gives the operating conditions of a few wells taken at random.

The difference of the conditions produced by intermittent injection as compared to straight flowing is clearly shown by the orifice meter chart (Fig. 8).

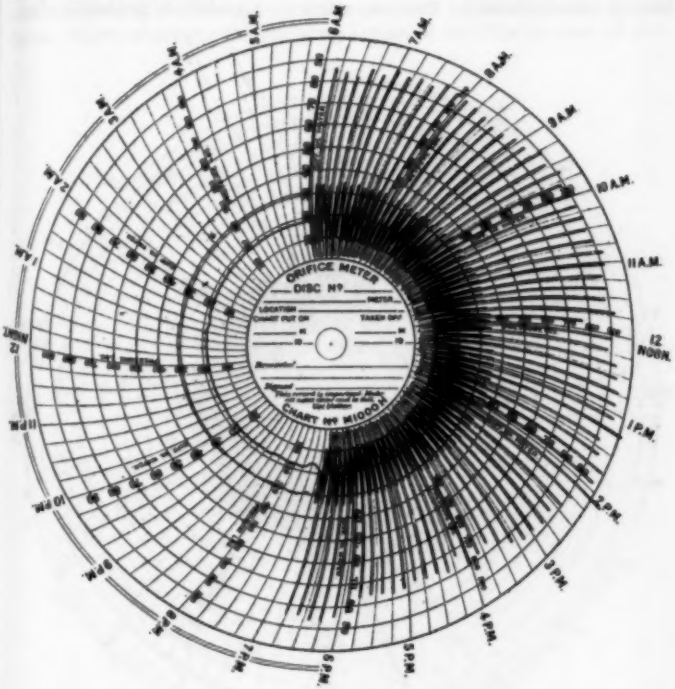

FIG. 8.

ORIFICE METER CHART FROM THE INPUT GAS LINE OF A WELL PRODUCED BY BOTH INTERMITTENT INJECTION AND STRAIGHT FLOWING.

On all the charts the static pressure is denoted by a thick line and the differential pressure by a thin line.

This chart is from a well making 300 bbls. of oil and 30 bbls. of water a day. For twelve hours the well was flowed intermittently, and for the remaining twelve hours the well was flowed straight.

It will be noticed that when flowing straight the working pressure is just under 180 lb./sq. in., when flowing intermittently the working pressure varies from just over 80 lb. to about 330 lb., the average pressure being between 160 and 170 lb./sq. in.

The corresponding trap chart is also shown (Fig. 9). It will be noted that the trap pressure is about 10 lb. sq./in. when the well is flowing straight and varies from about 7 lb. to 16 lb./sq. in. when flowing intermittently; this variation in pressure is probably due

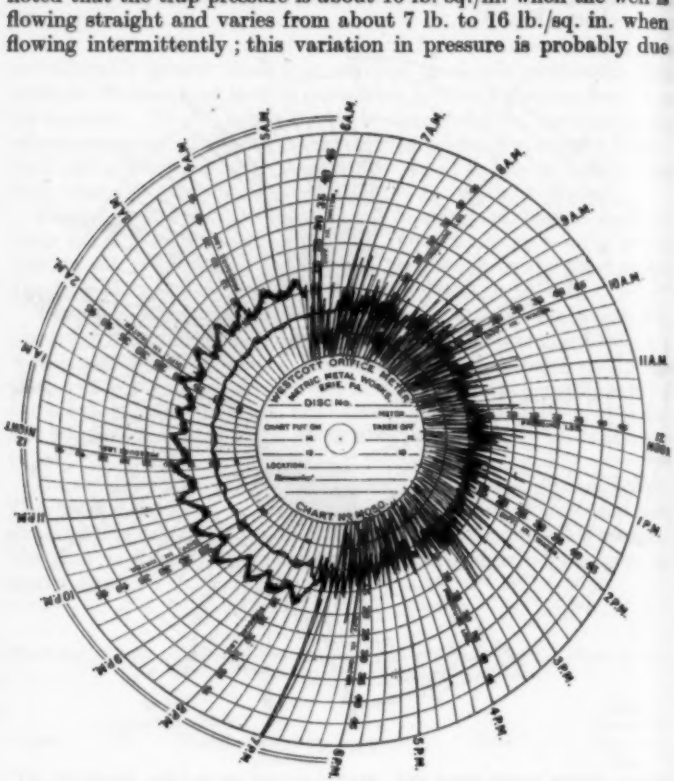

FIG. 9.

ORIFICE METER CHART TAKEN AT THE GAS TRAP ON THE SAME WELL AS FIG. 8.

to the sluggish action of the regulator. It will be noticed that the well breaks out at every "shot" or injection of gas, showing that the well is timed more or less correctly.

In order to show the effect of intermittent injection, charts taken with a two hour clock, instead of the usual twenty-four hour clock

are shown. The chart shown in Fig. 10 is from the intake meter, and Fig. 11 is from the trap meter taken simultaneously on a well making about 900 bbls. a day. The rush of gas filling up the line, and the gradual building up of the pressure is clearly seen on the intake chart, similarly the slugging action of the flow is seen on the

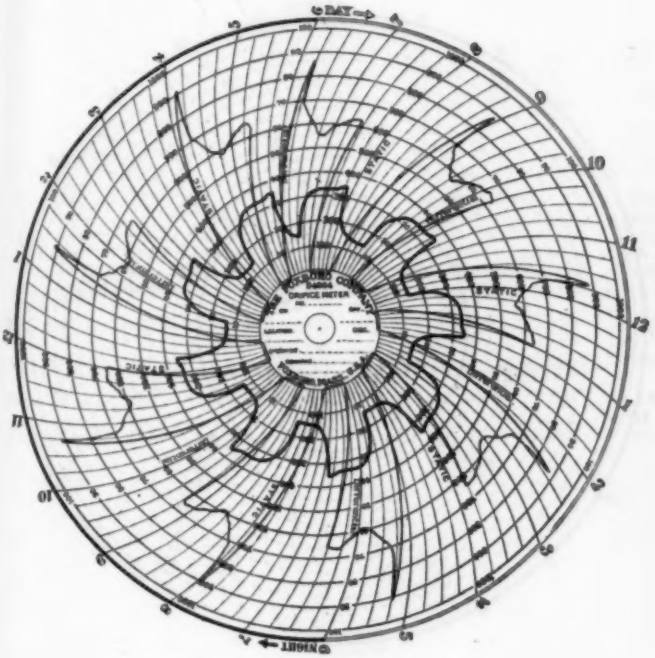

FIG. 10.

TWO HOUR CHART TAKEN ON THE INPUT GAS METER OF A WELL PRODUCED BY INTERMITTENT INJECTION.

trap chart; interesting and valuable information can be secured by the careful study of charts of this description. A twenty-four hour chart was used because no special two hour charts were available; one hour on the chart actually represents five minutes. The timing of the well was 8 minutes on, and 7 minutes 50 seconds off.

The gravity of the oil is often increased by intermittent injection, due to the fact that the oil is produced in slugs and that the gas does not blow through the oil to the same extent as in straight flowing. In one instance the gravity of the oil was raised from 36.78° to 37.38° Beaumé when a well was put on intermittent injection.

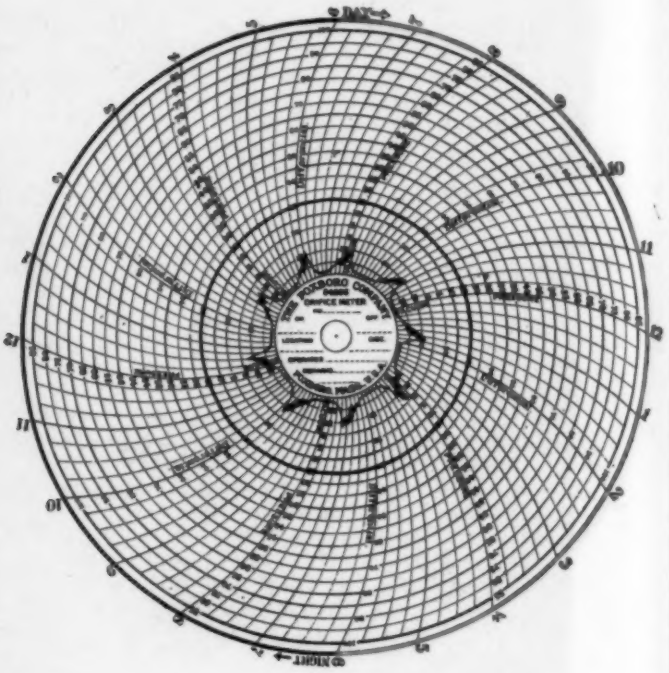

FIG. 11.

TWO HOUR CHART TAKEN ON THE TRAP METER OF THE SAME WELL AS FIG. 10 AND AT THE SAME TIME.

Unfortunately intermittent injection increases the gas-oil ratio due to the lowering of the well pressure during the off period, the differential pressure between the bore of the well and the formation is increased, and more gas comes into the well.

TABLE No. 2.

Operating conditions of wells on intermittent injection.

Date.	Well No.	No. of compressors.	Size.	Max. pressure, lb./sq. in.	Min. pressure, lb./sq. in.	Average pressure, lb./sq. in.	Vol. of inlet gas, M.cu. ft. 24 hrs.	Trap vol. M.cu. ft. 24 hrs.	Formational gas. M.cu. ft. 24 hrs.	Time on mins.	Time off mins.	Daily production. in Brls.		Daily production of total fluid in Brls.
												Water.	Oil.	
										M. s.	M. s.			
May 28 ..	A.	5	4-10in. × 6in. × 10in. 1-10in. × 4¼in × 10in.	320	130	210	678	775	97	3 30	10 0	—	425	425
May 31 ..	B.	4	3-10in. × 6in. × 10in. 1-10in. × 4¼in. × 10in.	340	140	210	1313	1608	295	7 0	7 0	—	898	898
June 16 ..	C.	6	4-10in. × 6in. × 10in. 2-10in. × 4¼in. × 10in.	435	135	300	702	956	254	3 30	7 12	145	200	345
June 16 .	D.	6	4-10in. × 6in. × 10in. 2-10in. × 4¼in. × 10in.	410	135	290	1050	1705	655	4 20	6 20	30	985	1015

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It would appear that the application of intermittent injection gives better results on wells whose rock pressure has declined than on wells which are still in the early stage of their lives.

Pumping.

Due to the crookedness of a good many of the holes in the field, the pumping of the wells presented a nice problem.

Generally speaking, wells are put on the pump when they have declined to a daily production of between 100 and 200 barrels. Most of the pumping wells are handling large volumes of salt water.

Rigs.—Although the ordinary standard rig predominates for pumping there are a large number of individual pumping units installed. The pumping unit makes an ideal installation for pumping a well. The balancing arrangement is effective and the unit gives a 24-hour service in any weather, belt troubles being eliminated.

The pumping unit is usually driven by a direct coupled electric motor, although a gas-driven motor can be used if desired.

A chain-driven rod and tubing hoist mounted on the derrick floor is used in conjunction with the unit, it operates as a hoist when running rods or tubing and as a sand reel when cleaning out.

The bull wheels are driven by a chain and sprocket from the hoist for cleaning-out purposes.

The equipment is strong enough for a light cleaning-out job, but seems to be rather lightly built for deepening these 4100 and 4200 foot holes, or if any heavy strains are imposed upon it.

Power.—Electric motors and gas engines are the source of power with the latter predominating.

Two systems for the application of electric power are used, the jack shaft or countershaft system and the reduction gear. In the latter case the motor is mounted directly on to an enclosed reduction gear, the pulley on the gear driving the band wheel by a belt in the usual way. The reduction gear is so made that it can be fitted directly on to the drilling engine blocks. The engine house can be made much smaller for the reduction gear installation than for the jack shaft arrangement.

Pumps.—Sand conditions are not severe and pulling expenses are almost all due to rod breakage. High fluid pressure due to the depth of the well is the main item to be considered when selecting a barrel.

Many types of barrels are used, the fluid packed, insert and plunger type having about an equal number of adherents.

2½ in. tubing is the size most generally used. The tubing is run with one elevator and the use of slips. The automatic tubing spider is often used.

Rods.—Rod trouble in the field has been excessive and has resulted in rod manufacturers looking more closely into the manufacture and heat treatment of their products, with a result that a great improvement in rods has resulted.

Rod guides have been tried to reduce rod and tubing wear, but their use is not general. ¾ in. and ⅞ in. rods are the common sizes.

Balancing.—The beam type of balance is in general use, a few band wheel balances are also used. The balancing of the wells leaves a lot of room for improvement.

The particulars of a few pumping wells, taken at random, are given :—

	Daily Production in Barrels.			
Well.	Oil.	Water.	Total Fluid.	Type of Barrel.
A	30	140	170	2½in.—15ft. Fluid Packed.
B	160	—	160	2½in—10ft. Axleson Seminole Special.
C	20	238	258	2½in.—15ft. Fluid Packed.
D	165	—	165	D. & B. Simplex (Liner Barrel).
E	105	220	325	„ „ „

Stock tanks or lease tanks.—The 1000-barrel capacity bolted stock tank is the most usual size of tank used for handling the flush production of the leases. These tanks have an internal diameter of 21 ft. 3 in. and a height of 16 ft. 2 in. On some leases as many as ten or twelve of these tanks were erected, and even with this large capacity there would often be only fifteen or twenty minutes "room" before it was necessary to switch tanks during the period of peak production.

As production declines several of the tanks become superfluous, they are then knocked down and removed to new leases.

The best practice is to entirely do away with the 1000-bbl. stock tank when the production becomes low and install a battery of 250 bbl. tanks or the low pattern 500-bbl. tank or the high 210-bbl. welded tank.

The 250-bbl. tank has an inside diameter of 14 ft. 9 in. and a height of 8 ft. 1 in. The 500-bbl. tank is simply the first ring of the 1000-bbl. tank.

The 210-bbl. tank is a welded steel tank having a diameter of 10 ft., a height of 15 ft. and weighing 7200 lb. As all the joints are welded this tank can be kept gas tight much more effectively than the bolted or deck pattern tanks. The 210-bbl. tank can be hauled around fairly easily without undue damage in handling, a battery of these tanks can, therefore, be installed much quicker than a battery of bolted tanks.

The idea of doing away with the large stock tank and installing a smaller tank is to prevent the oil from losing gravity, the reason for the oil losing gravity in a 1000-bbl. stock tank is twofold. In the first place with a low production it takes quite a time for a 1000-bbl. tank to fill up, it may take two days for a tank to fill. There is then every possibility of the oil having a lesser gravity (especially in hot weather) than if the tank was filled up and pumped out on the same day. Efforts are made to keep the tanks gas tight, but where hourly gauges are being taken it is almost impossible to prevent a loss in gravity. The second reason for a loss in gravity when using the large stock tank is due to the mechanical distillation of the oil as it drops from the flow line to the bottom of the tank (a distance of about 16 to 17 ft. on a 1000-bbl. tank). If the tank fills up rapidly, the loss of gravity from this cause is not noticed, but when it takes a couple of days or more to fill a tank, the loss becomes appreciable.

Wooden troughs or steel pipes are often placed in a high tank to carry the oil slowly to the bottom and prevent the direct fall of the oil.

The tanks are erected very rapidly, it takes about two days for a crew of five men to erect a 1000-bbl. bolted tank. This time can be reduced in an emergency.

Treating the oil.—When a well begins to cut b.s. and water a settling tank is installed and in some cases both a treating tank and a settling tank. The settling tank is usually one of the 1000-bbl. stock tanks with an additional ring of plates on the top making a 1500-bbl. tank. Steam heating coils are placed in the lower portion of the tank so that the oil and water can be heated during the cold weather. Sometimes the steam coils are dispensed with and the fluid is passed through a boiler before entering the settling tank, when it is necessary to heat it.

The oil does not readily emulsify; any emulsion that is formed is easily broken down. In hot weather no further treatment is required other than simply passing the oil through the hot salt water in the treating tank. In a few cases a reagent such as Tret-o-Lite or similar product must be used to help break down the emulsion.

The Tret-o-Lite is introduced into the lead line at the well either by means of a "boll weevil" (a form of displacement lubricator) or by a small pump. The supply of Tret-O-Lite can be regulated much finer with the pump than with the lubricator. The pump is actuated by a rod from the walking beam in the case of a pumping well or by a ¼-h.p. split phase electric motor and reduction gear in the case of a flowing or gas lift well. A small look box is placed

on the Tret-O-Lite line so that the amount of fluid that is going into the lead line can be seen.

The percentage of b.s. is generally greater on a well produced by the air-gas lift than on a pumping well, this is due to the greater agitation that the oil and water receive on their journey to the surface.

A well will also show a smaller percentage of b.s. when produced by intermittent injection than with straight flowing on the gas lift. Here again the reason is to be found in the smaller amount of mixing that the oil and water receive.

When a well is being produced by the gas lift, the Tret-O-Lite (which in this case is mixed with water or oil), is sometimes admitted into the inlet gas line. The Tret-O-Lite solution is carried down into the well with the inlet gas and tends to prevent the formation of emulsions. The working pressure necessary to flow a well is often reduced by adopting this method, if the Tret-O-Lite is effective in preventing the formation of emulsions.

A few "water" wells are tabulated :—

Location.	Method of Production.	Daily Production in barrels. Oil.	Water.	Temp. of Fluid.	Gals. of Tret-O-Lite used per day (Summer).
A	Pumping.	35	142	99° F.	None.
B	,,	18	238	98° F.	,,
C	Gas Lift.	382	150	88° F.	2
D	,,	590	420	92° F.	2
E	,,	851	300	98° F.	2

DISCUSSION.

Mr. A. E. Chambers said the paper was a very clear and instructive one, describing modern field work on one of the latest oilfields of America. A few of the members were old enough to remember when oilfield equipment looked rather like second-hand machinery from a farm yard, and when the chief characteristics of an oilfield superintendent were the habit of invective and ability to chew tobacco. If he might digress for a moment, he wished to remind the meeting that it was almost an open secret that a distinguished colleague of his on the Council was once mistaken for an old-time Oklahoma driller, although, needless to say, it was not for either of the two reasons that he had mentioned. The paper emphasised the great changes which had taken place since those early days. The machinery employed was now designed by competent engineers, and the people looking after it were trained to observe and make deductions from their observations. He could remember the old days when the usual saying on an oilfield was "I guess that'll do boys," when it generally did not do at all; but these haphazard methods were now things of the past. One point to which the

author did not refer, although a great deal had been written about it lately, was the subject of limiting the production. He would like to know if any of the producing wells on the oilfield described in the paper had their production limited, and if so what effect it had on the ultimate production of the wells. Another point was the measurement of deflection in wells, in connection with which the author mentioned the use of hydrochloric acid, and he had wondered if the photographic methods, about which some articles had appeared in the last year in the technical journals, were used with success in Oklahoma. He did not think the author mentioned either the application of stellite or some other composition to the cutting edges of the bits. A good deal in regard to that subject was heard a year or so ago, and he would like to know if it had been tried with success in Oklahoma. He noticed that the author mentioned that one or two cores were taken, and he presumed that in ordinary wells in proved territory that was all that was necessary, but in the wells in the outlying districts he imagined that many more cores would be taken. He would like to know if cores were more or less continuously taken from wells, and if so what particular coring devices were used.

Sir Frederick W. Black, K.C.B., said that being the individual who was referred to by the last speaker as having been described as "an old-time Oklahoma driller," he felt that he ought to join in the discussion with a few general remarks, but not pretending to criticise the paper from a technical standpoint. The value of the paper was largely the description of methods and mechanisms. He had been particularly struck, as Mr. Chambers had been, in regard to the great improvements that had been made in the last ten years in oil-field equipment, not only in the structure of the "derrick" but in the whole of the details of the mechanism now largely used on modern oilfields. Mr. Chambers had referred to the fact that the old-time driller said "That will do boys" when as a matter of fact it often would not do. Credit, however, should be given to the drillers for what they did during the war. It was his duty to visit the drillers in the Oklahoma fields, in Texas and elsewhere in America, and he found great energy shown in drilling and obtaining oil to meet allied needs. Mr. Chambers had alluded to the very important point of the control of the production of oil. There are strictly two questions involved, first the economic or administrative, and secondly the technical or engineering control. The regulation of the number of wells by arrangement with leaseholders is one thing, and is of course distinct from engineering problems. He hoped Mr. Capito, who had local knowledge on the latter point, would in the course of the discussion say something

about the methods used in regard to the engineering aspect of the control of production. He was told that there were fields at the present time on which the bringing in of the well was so managed that the oil was not allowed to escape uncontrolled, even for the briefest period when flow began. They were sometimes told that engineers had got so far ahead with their equipment and methods that they were responsible for the over-production that had taken place in recent years, but the engineers' reply to that statement was that they could control the flow from the well at any time that their commercial chiefs told them that they desired it to be controlled. He thanked the author for his instructive paper, and particularly for bringing to mind scenes that were familiar to him in the War period, and at the same time he desired to reiterate his previous comment that he was struck with the immense improvement in every detail of the mechanism that had taken place in the last ten years.

Mr. C. E. Capito said he quite agreed with what Mr. Chambers had said in regard to "the passing of the third floor back," or in other words, the passing of the old-timers. The control of the oilfields was now very much more scientific than it was in past times, when he had seen pipe-lines hung up almost with pieces of string and steam leaks everywhere. One point he had noticed in regard to the paper was the apparent ease of drilling in the Greater Seminole field, to get one string of casing with only a 300 ft. conductor down to 4,000 ft. seemed almost too good to be true. He had been accustomed to think that if he got three strings down to 3,000 ft. they were doing very good work and deserved to be patted on the back. Another point he wished to raise related to the use of a welding plant. If reliance was placed on welding the casing heads and not on their being screwed, a welding plant being brought up alongside the rig, he thought trouble would ensue if a show of gas was suddenly struck. He presumed in Oklahoma the engineers knew exactly where they were in that respect. In his own case he had always been accustomed to have the heads thoroughly screwed, a really tight joint being made.

Mr. Heseldin, interposing, said the reference he had made to welding applied only to the connection work at the traps and not on the casing head.

Mr. Capito said he did not wish to say anything against welding in general, but it must be remembered that if a show of oil or gas at high pressure was suddenly struck a welding plant could not be brought alongside the rig. It was necessary then to rely on well-cut screw threads, otherwise trouble occurred. He noticed also the

author stated that 100 ft. of cement were left in the hole when it was cemented. That seemed to him to be a tremendous amount of cement to leave in the hole and to be a particularly dangerous practice. Personally, he generally tried to leave not more than from 3 to 5 ft., the latter figure being considered quite a large amount, for the reason that when drilling was started again on the hardened cement the shaking and vibration of the tools against the walls of the casing was liable to crack the cement on the outside of the casing unless a very large hole was being drilled in comparison with the size of the casing put in. He had generally drilled with an eccentric bit, which drilled a hole 1½ in. larger in diameter than the outside diameter of the casing used, allowing only ¾ in. cement round the casing, and if one had to drill 100 ft. of cement inside the casing it seemed to him that was rather too much for safety. Another point he desired to refer to was the use of feed water heaters. He was afraid he had seen a great many plants in which feed water heaters had never been thought of, but he was glad to see that an endeavour was now being made to economise in that respect. With regard to the control gear for drilling in, various containers could now be obtained to put on the top of the casing head through which the tools could be drawn. He did not know whether that system was used in Oklahoma. The tools were drawn up into the container; the valves on the casing were then shut and the tools were changed when necessary. They generally tried to get the last string cemented, the whole of the casing being tested to about 500 lbs. pressure, and if there was the slightest leak no further drilling was done until it was remedied, so that not even a bubble was given off.

Mr. B. J. Ellis said the author had given a very good idea of the brute force methods of American oilfield practice as opposed to the methods, more in accordance with ordinary engineering practice, which were generally adopted or fostered by companies operating away from American influence. It had to be admitted at once that American methods "got there" and that as each new problem arose a means of getting over it was quickly found. On the other hand, it had to be admitted that, generally speaking, European methods had not given such good results, and that there were many problems in oil production confronting the European oil companies that had been before them for years and had not yet been solved. Most of the companies had ideas that vast reserves of oil lay below or near those which they were at present tapping, and it would be of immense value to them if they could know whether there was any foundation for their surmises or not. With the intention of finding out, they started deep tests

on their existing oilfields and tests on outside structures generally with the idea of going as deep as possible. How unsuccessful those tests were as far as depth was concerned could be gauged from the fact that an insignificant number of those wells had reached 6,000 ft. and not one had got to the 7,000 ft. and over depth which was now a common producing depth on some American fields. It would be of interest to try and see wherein European methods failed, and he thought the reason could be found in the lack of appreciation that the time factor was more important in drilling than any other consideration. The American operator did not concern himself with the cost of plant, labour or fuel until he came to reckon up the cost per foot of the finished well, whereas the European operator was more inclined to count those costs before the well was drilled and to make economy in those the chief consideration. To drill deep wells a large force constantly applied was required. One man could not close a 1 in. rivet properly with a 1 lb. hammer if he tried for a month, but three men with 2 lb. hammers and a sledge could do it in under a minute. They had become accustomed to the fact that three men or more were required to close a rivet—which really looked only a one man job—though they did not as a rule relate that requirement of men to the time factor. In drilling they had not yet—as the Americans had—become accustomed to the fact that enormous force and high speed was essential and that the size and quantity of the drilling machinery and the number of men had to be adjusted accordingly. The American producer thought only of speed in the first instance and found that his costs looked after themselves. In general, the cost per foot was inversely proportional to speed, no matter what amount was spent on tools, men and fuel. More men, fuel and tools meant more speed, and, therefore, the American producer provided them.

Turning to the actual details of the operations as described by the author, there were several features which were bad in the Seminole practice and for which the producers had, or would eventually have, to pay. The use of liners, set by breaking the string with a collar buster; the crookedness of holes; the imperfect arrangements for mud settling; boilers run above their safe working pressure; 1½ in. lines on 18 in. diameter draw-works drums; carelessness in the use of quick set reagents in cement, were all bad features which could be made better with very little trouble and if attended to would result in a reduction of drilling and producing costs. Attention to them, however, might reduce speed so they were left as unimportant. Interesting new features tending to increase speed were the K.P. drilling bit, the use of Hughes bits with colossal slush pumps, the setting of pumps low down on

the ground and the abolition of foot valves on the suctions, the Brauer Automatic Manifold Valve, 1¼ in. diameter rotary casing lines, slip elevators, and, of course, gas lift on the scale it had been operated in Seminole. All those were worthy of full consideration by field superintendents in other areas. It was also interesting to note the high speed cementing methods, and there one might suggest that a combination of the two methods described might be advantageous.

There were a few points on which he should like additional information, firstly, was the K.P. bit inclined or not to leave its cutters in the hole? The tendency of recent years had been to get away from loose cutters and the K.P. bit indicated a reversal of that tendency. Secondly, had 1¼ in. diameter lines been adopted simply to handle the huge power of the 12 in. by 12 in. drilling engine, or were they better all round than the 1 in. line? Thirdly, why was the cable tool system used for drilling in? Were the operators frightened that the mud would mud off the oil, or was it merely a continuance of Mid-Continent customs? Fourthly, what was the minimum production in which gas lift was used on the field, *i.e.* at what point was a well put on the pump? Perhaps the author would find time to enlighten him.

Mr. H. G. Austin said that having spent a considerable time during 1927 in the Seminole Area, the paper was of particular interest to him.

The author had mentioned that some of the drilling contractors were very successful, the statement being made that one of the largest firms of contractors in the field operated 14 strings of tools and had its own private aeroplane. During the time of his visit to the Seminole field, it was very evident that many former drillers and drilling superintendents had purchased drilling rigs in order to take advantage of the great amount of drilling work which was being done there in the early days of development. When, however, over-production, and consequent lack of drilling contracts, was being experienced, many of the smaller contractors were forced out of business, losing their rigs, and often reverting to their former status of driller.

Mr. Chambers had asked a question with regard to the use of stellite or other hard-wearing facing metals on fish tail bits. Due to the early introduction of the K.P. bit, the fish tail bit was very rarely used, and then only for the purpose of drilling through the softer formations. He could not remember having seen any stellited bits in any part of the Seminole area. The K.P. bit had the front cutting surfaces hardened only. Consequently, regardless of the amount of wear on the cutters or reamers, a very sharp

cutting edge was maintained. Often the bits were brought out of the hole with cutting edges as sharp as those of a new bit. The development and success of the K.P. bit he thought was the chief reason why stellite had not been used for facing fish-tail bits in Seminole.

Regarding the running of disc bits behind a three or four point reamer—in the early days, before the introduction of this type of reamer, the holes were very often in a bad shape due to the use of disc bits, without running a fish-tail or a rock bit to ream out. Very often, when running-in or coming-out of the hole, the disc bit would back off. As mentioned by the author, a rock bit would frequently hang up, and the average of rigs skidded on account of lost tools and pipe was rather high throughout the area.

To those connected with the development of oilfields outside the U.S.A., California had always been looked to as the place from whence all improvements in oilfield equipment came. The severe conditions and the abuse given drilling material in Seminole in the demand for faster drilling called for heavier rigs than those in general use. The supply companies therefore took advantage of the opportunity of testing out the heavier equipment (which was bound to come sooner or later) in Seminole, and one found there the very latest types of long-stroke pumps, high pressure boilers, heavy hoists and rotaries.

He noticed the author had stated that a comparatively small number of spare parts for pumps were used, but he rather questioned the accuracy of that statement. From personal experience, and from statements made by several contractors, as much as $500 for spare parts for each pump, per well, had to be expended. This was probably due to the very inefficient baffling and settling arrangements in the mud pits, generally in use. With the amount of "red-bed" encountered throughout the district, very often one found more sand than mud being pumped through the slush pumps. He was, of course, referring to general practice, although several operating companies and contractors took very great care with their mud supply arrangements.

He desired to defend the average cable tool driller employed in Seminole against the statement made by the author that the temper screw was never run, as it was intended, but that, with the exception of fishing operations, the rope was slipped through the clamps only. He himself had done that once, and it was the last time. After what he had heard about the subject from the contractor, who happened to be present, he did not do so again. It is true that after running out the screw, very often one would slip the clamps, until it was time to run the bailer, but the statement made to the effect that it was general practice around the area to

slip the clamps only, except on fishing jobs, was not accurate, according to his observation and experience. It was far too hard on the line, to start with, and furthermore, led to frequent drilling with a loose line, which was hard on the joints of the tools. It was not possible accurately to slip the required amount of line every time, and often, when the line was slipped, it was necessary to throw on the bull ropes and clamp on again.

He noticed the author mentioned the cost of cementing an 8¼ in. string of casing as $250·00. Field men might be surprised at the apparently low cost of such an operation, and he believed that this figure represented only the cost of hiring the cementing truck and equipment, together with the attendance of the two experts—it did not include the cost of the cement, accelerator solution or the extra labour.

He would very much like to hear of the results of lubricating "Tret-o-Lite" into the air line or gas line of an air-lift or gas-lift system raising an emulsion from a well. The author had not mentioned the outcome of the experiments, and it would be of general interest to hear whether the emulsion showed any signs of settling out in the trap.

Mr. G. Heseldin, in reply, said that the first question, raised by Mr. Chambers, related to over-production and its curtailment. In Seminole there had been a prohibition of drilling in any of the areas which were known to be productive by means of wild cat wells. The production of wild cat wells was kept down, he thought, to 200 or 300 barrels a day, and a date several months ahead was decided on when a series of test wells should be drilled. Each company was allowed to drill one test well to prove its lease in the vicinity. Later on another date was settled when general drilling should start, and the quantity was reduced by allowing only two wells out of every 40 to be used, compared with the usual practice of four wells out of every 40. Speaking from memory, he believed the maximum production allowed was 1,600 barrels to 40 wells. Wells were also not allowed to be shot except in one or two areas. Again, in the new Little River extension the use of the air gas lift for production was forbidden. The air gas lift was the *bête noire* of the old-time people because they thought it was the cause of all their troubles, and they had got their way by inducing the Government to prohibit its use in the Little River extension. It was rather interesting to note that in the Little River extension 73 rotary tools spudded in on the same day, a never to be forgotten sight. Those concerned were allowed a certain time in which to drill in and to allow the wells to run wild. In most of the wells the period was five days, but in some of the slow ones it was only a day. After that period they were only allowed to produce 1,600 barrels to 40 wells and production was reduced in that way.

An answer had already been given to the question asked in regard to the use of stellite, personally he had never seen any used. The K.P. bits were made out of special steel and were very hard, and therefore did not require the use of stellite. With regard to the question asked about coring, in some wild cat wells in the outlying regions coring was done occasionally. The only coring with which he was acquainted was done with the Alco tool and more recently with the Hughes coring tool. If the members had seen the Hughes coring tool they would know it was a very fine piece of work and that it was possible with it to get a core in any formation, no matter how hard it was. The tools were run by the ordinary driller. On the well at which he worked he took three cores, two with the Alco and one with the Hughes, and obtained good samples every time. One of the reasons why cores were not run was the very efficient methods that existed for sampling the returns. On the particular well to which he had referred at which the core tool was run three times there was really no necessity to run it at all. They knew the formation and they simply ran the core in order to get a check. By taking and analysing the samples carefully it was possible to tell where one was in a rotary hole, provided the work was done carefully. In reply to Mr. Capito the author said a question had been asked in regard to welding. Welding work was done in the pipe-line connections, all traps and lines were in place before the well was drilled in. Regarding cementation there were two reasons for leaving 100 ft. in the hole, the first being that the excess water came to the top of the column of cement in the hole and left at the top a weak cement, as much as perhaps 100 ft. being weak. Another reason was that it was quite possible for some of the mud to leak past the plug and contaminate the cement. No difficulty was experienced in drilling out the 100 ft. of cement if it was done carefully and slowly with standard tools, and he had not heard of any failures due to that cause. Cement was not used in Seminole for shutting off high-pressure water sands; in fact, after working in high pressure areas it was rather a simple cementing job. In any case there would be no difficulty in drilling out with a rotary. Replying to Mr. B. J. Ellis the author said that as far as his experience went in other oilfields, the drilling on the Greater Seminole field was fairly easy, especially down to 2,600 ft. Nobody cared how much there was on the brake until a depth of 2,600 ft. was reached, and then one began to take notice. This was largely due to the formation being fairly consolidated, no soft or running sands being met with. The chief drilling difficulty was the hanging up of the rock bit when coming out of the hole, all the drillers were "scared stiff" of getting the rock bit hung up when coming out of the hole. That might be due to the use of

too heavy mud in some cases or to some squeezing formations in the soft shales. Unfortunately only a small check was kept on the mud used, and some of the drillers used it far too heavy. The mud was very good, in fact the best he had ever seen, and it was easily made. The K.P. bit never gave any trouble, the cutters being held very securely in the body of the tool, and he had never heard of any coming off. The gas lift was usually put on when the well declined to 100 or 200 barrels. There were isolated instances in which 30 barrels a days were produced on the gas lift. It all depended on the particular part of the oilfield that was being operated. When all the companies were using the gas lift one company took their wells off the gas lift and put them on the pump, increasing their production about 75 per cent., until "the other birds got wise," to use an American expression. Some people swabbed for the same reason, thinking that the people in the adjoining well were driving the oil to them. The production on a swabbed well was not affected by the change over from the gas lift to a pumping well. Referring to Mr. Austin's remarks the author said the question of the wear on the pumps had been raised. Mr. Austin was in Seminole probably six months or a year before he (the author) was there. Personally, during his stay he saw a very marked improvement in the mud settling arrangements that were adopted, and that, of course, was the secret of the wear on the pumps. He had seen some rotary samples taken containing as much as 90 to 95 per cent. of recirculating material in it, *i.e.*, sand and shale drawn through the pump, only 5 per cent. of the rotary sample consisting of true genuine cuttings. No pump would stand that sort of thing for long. Where the slush pit arrangements were good that did not occur. With regard to another point raised by Mr. Austin, personally he never saw a temper screw used. A slipping line was always adopted, and those concerned were very clever in its use. The holes were very crooked and the wear on the line was excessive in the hole, so that he did not think much was saved on lines by using a temper screw. At the same time there was a great increase in drilling speed by slipping the line. The price quoted for cementing was that paid to the cement contractor for his portion of the work. With regard to the question of emulsion and the use of Tret-o-Lite in the gas lift. The process was only in its experimental stage when he left the field and some wells were reducing the working pressure. In some wells the Tret-o-Lite broke down the emulsion, but in others it did not have any effect. At the moment it was an entirely separate question for every particular well, the process had only been tried in the last few months, so that he could not give any definite figures in regard to it.

The President said he was sure he was expressing the desire of everyone present when he proposed that a most hearty vote of thanks be offered to Mr. Heseldin for reading such an absorbingly interesting paper, which would prove of great value in the Proceedings.

The resolution of thanks was carried by acclamation, and the meeting terminated.

The Bearing of Base Exchange on the Genesis of Petroleum.*

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Introduction.

The increasing importance now attached to the phenomenon of base exchange between soil and solutions of neutral salts in connection with agriculture has led to the investigation of the properties of the various types of clay. The results of these investigations are not only important from the agricultural point of view but find an application in all cases in which strata containing clay have been deposited under marine or estuarine conditions, since, under such conditions, the clay in the sediment is brought in contact with a solution of sodium chloride. In connection with agriculture, the subject has been investigated from the point of view of the application of fertilisers to the soil and the reclamation of salt and alkaline land. As the deposition of sediments under marine or estuarine conditions has been taking place throughout geological time, base exchange is a phenomenon that is associated with strata of all geological ages. From observations that have been made, base exchange appears to be particularly associated with shales—varying from the finest-grained to those classified as sandstones—and marine and estuarine clays. Base exchange is, therefore, important from the geological as well as from the agricultural standpoint. The study of the geological application of base exchange has so far been confined to the investigation of those deposits in which coal—lignite, bituminous coal and anthracite—occurs.[1] The possible importance

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[1] E. McK. Taylor: (*a*) The Replaceable Bases in the Roofs of Bituminous Coal Seams of Carboniferous Age, *Fuel*, 1928, 7, 66-71; (*b*) The Replaceable Bases in the Roofs of Bituminous Coal Seams of Cretaceous Age, *Fuel*, 1928, 7, 127-128; (*c*) The Replaceable Bases in the Roofs of Bituminous Coal Seams of Tertiary Age, *Fuel*, 1928, 7, 129-130; (*d*) The Replaceable Bases in the Roofs of Anthracite Seams, *Fuel*, 1928, 7, 228-229; (*e*) The Replaceable Bases in the Roofs of Lignite Seams, *Fuel*, 1928, 7, 227-228; (*f*) Base Exchange and the Formation of Coal, *Fuel*, 1928, 7, 230-238.

of base exchange in connection with the genesis of petroleum is indicated by the literature on the conditions of occurrence of petroleum. Petroleum differs from coal in that it may not now be situated in the position in which it was formed. There are, however, numerous instances in which it can be presumed that the reservoir rock is also the mother rock so that the conditions under which the petroleum was formed can be studied. Orton[2] states: "So common is the occurrence of petroleum in stratified rocks, that wherever a close-grained shale occurs there is almost always at least a small accumulation of oil directly underneath it." This may be somewhat exaggerated, but it indicates the close association between shale and underlying oil. The same author again says: "Almost every important mass of shale in the Ohio Series has been proved to be somewhere the cover of accumulated petroleum." Arnold[3] says that the petroleum in the porous Miocene strata of California is dependent on the presence or absence of the Eocene shales. Clark[4] states: "Oil formation is at least as normal a phase of sedimentation as that of coal"; and again: "Palæographic studies of several Tertiary oilfields indicate the importance of gulf or inland sea conditions in the deposition of petroliferous sediments." Beeby Thompson[5] states: "In Tertiary fields deltaic or estuarine characteristics are especially marked"; and further: "Most oil geologists now associate the source of hydrocarbons with clays and shales which predominate in oil measures." He later says: "Petroleum occurs more commonly in rocks of marine origin." Wade[6], discussing oil in Papua, states that the deposits were laid down in a huge tropical delta. In Trinidad the main oil-bearing formations are essentially marine. Prof. Illing (in the discussion of Clark's paper[4]), stated that the research "demands a theory of oil origin pene-contemporaneous with the sediments and not as the distillation theory would suppose as a later process of metamorphism. This favours the bacteriological theory of oil formation." These extracts, which might be multiplied almost indefinitely, indicate that the process of oil formation is connected with sediments formed under marine or estuarine conditions. As base exchange is a phenomenon always associated with the deposition of clay particles under these

[2] Sir Boverton Redwood, "A Treatise on Petroleum," 4th edition, vol. 1, p. 161, London, 1922.
[3] R. Arnold, *U.S. Geol. Survey Bulls.*, Nos. 357 and 398.
[4] E. Clark, "Organic Theories of Oil Origin," *Journ. Inst. Petr. Techn.*, 1926, 12, 257-287.
[5] A. Beeby Thompson, "Oil Field Exploration and Development," vol. I., p. 15, London, 1925.
[6] A. Wade, "The Search for Oil in Australia," *Journ. Inst. Petr. Techn.*, 1926, 12, 148.

conditions, the importance of a study of the subject in connection with petroleum bearing strata is evident.

The Phenomenon of Base Exchange.

In 1850 Way[7] investigated the reaction between soil and solutions of neutral salts of potassium and ammonium. He showed that whenever the soil is brought in contact with solutions of ammonium or potassium salts, some of the base is fixed by the soil and calcium appears in solution. Way's investigations were confined to the study of the action of potassium and ammonium salts as these were used as fertilisers, but it was later demonstrated by Mondésir[8] that sodium salts react in a similar manner. The process by which the ammonium, potassium or sodium is removed from the solution and calcium passes into solution is known as base exchange. The result of such an exchange of bases is to alter considerably the chemical, physical and biological properties of the soil. In recent years, the investigations of Gedroiz[9] and Hissink[10] have considerably increased our knowledge of the reactions involved.

Since the clay fraction of a soil shows marked flocculation phenomena, it indicates that the clay particles are charged. The present conception is that the charge on the particle is negative, due to the anions of the clay, and surrounding them are the positively charged kations, hydrogen, calcium, magnesium, potassium and sodium. It is thus possible to have a series of clay types according to the kations present. The most important clay types are hydrogen clay, characteristic of an acid soil; calcium clay, the normal constituent of agricultural land and of silt carried and deposited in fresh water; and sodium clay, which is the characteristic clay in salt and alkaline land. From the geological point of view, calcium clay and sodium clay are the most important as they are characteristic of fresh water and marine conditions respectively.

If calcium clay is treated with a solution of sodium chloride, base exchange will take place and the reaction may be represented by the following equation:—

$$Ca_n\text{—Clay} + 2n.Na\,Cl = Na_{2n}\text{—Clay} + nCa\,Cl_2$$

Thus, when a silt containing calcium clay is carried in suspension

[7] J. T. Way, "On the Power of Soils to Absorb Manure," *J. Roy. Agric. Soc.*, 1850, **11**, 313-379; *ibid.*, 1852, **13**, 123-143.

[8] Paul de Mondésir, "Sur le role du pouvoir absorbant des terres dans la formation des carbonates de soude naturels," *Compt. Rend.*, 1888, **106**, 459-462.

[9] K. K. Gedroiz, "Sodium Carbonate in Soils. Alkali Soils and Saline Soils," *Zhur. Opit. Agron.*, 1912, **13**, 363-420.

[10] D. J. Hissink, "Base Exchange in Soils," *Trans. Far. Soc.*, 1925, **20**, 551-566.

and deposited in water containing sodium chloride, the sediment will contain sodium clay as a characteristic constituent. Other methods by which sodium clay may be formed are (1) the submergence of strata in sea water, and (2) by the capillary rise of sodium chloride solutions from a sub-soil water-table containing this salt in solution. These two latter modes of formation are characteristic of deltaic deposits. It will be seen, therefore, that sodium clay is a characteristic constituent of sediments formed under marine, estuarine or deltaic conditions, and that calcium clay is only associated with fresh water sediments.

The Properties of Sodium Clay.

If some sodium clay is placed in a funnel and treated with a solution of sodium chloride, it will be found that the sodium clay is permeable, the clay particles being flocculated. On replacing the sodium chloride solution with pure water, it will be seen that the rate of percolation rapidly decreases, the percolate contains deflocculated clay in suspension, the percolate becomes alkaline and, finally, the sodium clay becomes impermeable. It will also be found that the sodium clay residue on suspension in water is alkaline. This series of reactions is exceedingly important both agriculturally and geologically. The properties that are of geological importance are those which render the land unsuitable for agriculture and, hence, have not been studied previously from the point of view of their possible beneficial effects.

Since the sodium clay remains flocculated in the presence of sodium chloride, it is stable in the presence of excess of that salt. Further, a suspension of the sodium clay in sodium chloride solution is not alkaline. When the solution of the neutral sodium salt is replaced by pure water, the sodium clay is no longer stable but is hydrolysed, free hydroxyl ions appearing in the solution which becomes alkaline. The action of pure water on sodium clay may be represented by the following equation:

$$Na_{2n}\text{—Clay} + 2nH\cdot OH = 2n.NaOH + H_{2n}\text{—Clay}.$$

It will be seen that the hydrolysis of the sodium clay results in the production of a solution of sodium hydroxide and that the residue is a hydrogen clay. That the sodium clay is capable of hydrolysis in fresh water and that, on hydrolysis, it yields an alkaline solution are extremely important properties of the complex, as, by its presence, it is capable of creating a medium in which the action of bacteria is not inhibited by the accumulation of their own toxic products, which are of an acidic nature. The hydrolysis of the sodium clay, and the consequent increase in the alkalinity of the solution, continues until equilibrium is established between the sodium ions in solution and those in the hydrolysing sodium clay. If by some means

such as neutralisation with an acid, a reduction in the number of hydroxyl ions occurs, further hydrolysis of the sodium clay takes place until equilibrium is again established. The hydrolysis of a sodium clay, therefore, affords a method by which the alkalinity of a solution or medium may be maintained for a considerable period.

Again, so long as the sodium clay is in the presence of the neutral sodium salt, the sodium clay remains permeable. When the excess of the neutral sodium salt is gradually removed by washing with water, the mass gradually becomes impermeable to both water and gases due to the deflocculating effect of the alkaline solution. The impermeability of the hydrolysing sodium clay to both water and gases is another important property of the material. In the first place, the impermeability of the sodium clay to gases is important because any bacterial decomposition taking place either in or under such a layer must be carried on under anaerobic conditions soon after the process has started, since no oxygen could pass either from the atmosphere direct or in solution through the impermeable layer. All bacterial decompositions of organic matter taking place either in or under a layer of hydrolysing sodium clay must be of an anærobic type and, hence, reducing in character so far as the residue of the organic material is concerned. A second result of the impermeability of the hydrolysing sodium clay is that gas generated beneath it will accumulate under pressure. This has been demonstrated in the laboratory experiments and will be referred to again. The presence of sodium clay, therefore, affords a method by which material, after deposition, may be sealed, and any products of decomposition prevented from escaping.

The power of the sodium clay to produce impermeability is illustrated by the occurrence of an alkaline sand at Delingat, Lower Egypt. This sand is perfectly impermeable to water, and behaves physically like the heaviest clay. The sand contains under five per cent. of clay, the remainder being composed of coarse and fine sand fractions. The clay is, however, a sodium clay, and is so distributed through the mass of the sand that it is able to impress its characteristic properties on the whole.

The properties of sodium clay may be summarised as follows:

(1) Sodium clay is stable in the presence of excess of sodium chloride.

(2) Sodium clay can be hydrolysed in fresh water and as a result yields an alkaline solution containing sodium hydroxide.

(3) If the equilibrium between ions in the unhydrolysed sodium clay and the ions in solution is disturbed, further hydrolysis of the sodium clay will take place until equilibrium is again

established. The presence of sodium clay, therefore, provides a method by which the continuous alkalinity of a medium may be maintained and the toxic acidic products of bacterial action neutralised.

(4) Strata in which hydrolysing sodium clay is present are impermeable. Conditions either in or under such strata are anærobic. The residues of bacterial decomposition either in or under such strata must, therefore, be reduction products.

(5) The impermeability of strata containing hydrolysing sodium clay results in the sealing of material under such strata.

THE PROPERTIES OF CALCIUM CLAY.

The properties of calcium clay differ considerably from those of sodium clay. The hydrolysis of calcium clay is a much slower process and the alkali produced, calcium hydroxide, is much weaker than sodium hydroxide. Investigations in the laboratory have shown that the hydrolysis of the calcium clay does not take place sufficiently rapidly to maintain the alkalinity of a medium in which bacterial decomposition is taking place. Acidic products of the decomposition accumulate so that bacterial action soon ceases.

A further difference is that calcium clay is flocculated in the presence of fresh water. As a result it is permeable to both water and gases. In the laboratory it has been shown that gas produced under such a layer by bacterial action does not accumulate but passes through the layer to the surface. A deposit of organic material situated under such a layer is not sealed as is the case with sodium clay. As calcium clay is permeable, the bacterial decomposition carried on in or under such a layer may not be anærobic in character. The decomposition normally taking place in agricultural land containing calcium clay is of an oxidising nature. It will be impossible, therefore, for reduction residues to be formed either in or under such a layer.

From the discussion of the properties of sodium clay and calcium clay it will be seen that if a silt is carried in fresh water and deposited under marine, estuarine or deltaic conditions, base exchange will take place and sodium clay will be formed. If subsequently the sodium clay is brought in contact with fresh water it will become alkaline and impermeable as the result of hydrolysis. The properties which the sediment will now possess will be those of the hydrolysing sodium clay just discussed.

EXAMINATION OF THE SHALES AND CLAYS OVERLYING PETROLIFEROUS STRATA.

If the shales overlying petroliferous strata have undergone base exchange with sodium chloride and subsequent hydrolysis

in fresh water, they should show evidence of it in their alkalinity and in the nature of the replaceable bases which they contain. While the number of shales examined so far is not large, the results obtained are significant since no exception has yet been found.

Two methods of examination of the shales have been adopted: (*a*) the determination of the pH value of a suspension in water, and (*b*) the determination of the replaceable calcium and sodium.

(*a*) *Determination of pH value.*—The shale was ground to pass the "100" sieve (100 meshes to the linear inch). Ten grams of the ground material were suspended in 50 cc. of water and allowed to stand for half an hour. The pH value of the suspension was then determined.

(*b*) *Determination of the replaceable calcium and sodium.*—The shale was ground to pass the 100 sieve and 25 g. of the ground material were suspended in 250 cc. of normal ammonium chloride solution for a period of twenty-four hours. The suspension was filtered and the residue on the filter paper washed with a further 250 cc. of normal ammonium chloride solution, the washings being added to the original filtrate. Calcium and sodium were determined in the bulked filtrate, the results being expressed as milligram equivalents per 100 g. of shale.

The specimens examined were obtained from Rumania and the West Indies. The following is the description of the specimens.

RUMANIAN SPECIMENS.

(1) Sample of the Meotian, 1,014 m. deep. One metre from third oil sand of Moreni. Well situated about 250 m. from edge of the salt. At this particular well, production was soon accompanied by salt water. The oil was a paraffin base oil. Specimen was a grey shale.

(2) From well north of No. (1) situated 50 m. from edge of salt. Sample taken from immediately above the "intermediate" oil sand, *i.e.*, a sand which lies between the second oil and some 17 to 20 m. above the third oil. Oil paraffin base.

(3) From the Meotian of Chicura where the oil is of the light Bustenari type. The depth of sampling was 596 m. or 3 m. above an oil sand.

(4) Meotian, Runca (?). Depth of sample 340 m. Immediately above a weak oil sand. Oil of light Bustenari type.

SPECIMENS FROM WEST INDIES.

(5) Well No. 210, El Mene. Sample from 916 ft. Cap rock of oil sand.

(6) Well No. 215, El Mene. Sample from 910 ft.

(7) Well No. 209, El Mene. Sample from 1,085—1,090 ft.

(8) Well No. 216, El Mene. Sample from 310—320 ft.

(9) Well No. 2, Mauwa. Sample from 965—980 ft.

(10) Well No. 1, Media. Sample from 1,150—1,160 ft.

All the above specimens were grey shales or clays. They were examined by the methods described for pH value and replaceable bases. The results obtained are shown in Table I.

TABLE I.

pH Values and replaceable bases in shales overlying oil sands in Rumania and West Indies.

Spec. No.	pH Value.	Replaceable bases (milligram equivalents per 100 g.). Ca.	Na.
1	9·0	4·1	73·7
2	9·0	3·8	13·6
3	10·2	2·8	16·5
4	10·5	3·9	27·1
5	9·0	1·6	7·0
6	9·2	2·1	10·8
7	9·4	5·2	15·8
8	9·2	3·5	15·7
9	8·8	3·0	9·6
10	10·5	8·2	18·6

From Table I. it will be seen that all the shales are alkaline. Further, as the maximum alkalinity of a calcium clay is indicated by the pH value 8·3, from the pH values alone it would be expected that sodium clay was the predominant type of clay present. This is confirmed by the determinations of the replaceable calcium and sodium in the shales. In each instance the replaceable sodium is higher than the replaceable calcium. This feature is characteristic of clays which have been in contact with solutions of sodium salts. In sediments deposited in fresh water and which have not subsequently been in contact with solutions of sodium salts, the replaceable calcium is always in excess of the replaceable sodium. From the results in Table I. it may be concluded, therefore, that sodium clay is a characteristic constituent of the shales overlying the oil sands examined While the number of specimens so far examined is small, the fact that they have been obtained from widely separated areas and yet agree in their essential characteristics is significant. It is too early to say that all the shales overlying oil sands are alkaline, but it can safely be stated that whenever the sediment has been formed under marine, estuarine or deltaic conditions, it will have undergone base exchange. Before alkalinity and impermeability can develop it is essential that the sodium chloride should have been leached away from the sediment by

fresh water and that hydrolysis should have taken place. Even though the conditions of deposition indicate that base exchange must have taken place, it is essential to examine the shales to determine whether the second set of conditions—leaching and hydrolysis in fresh water—have also been present. If the shales are found to be alkaline it is a certain indication that leaching and hydrolysis must have occurred.

In the case of the shales examined, it can be concluded that they were deposited under such conditions that base exchange with solutions of sodium chloride occurred, and that subsequently leaching and hydrolysis of the sodium clay in fresh water took place. It has been shown in the discussion of the properties of sodium clay that these series of reactions would impose continuously alkaline anærobic conditions on any bacterial decomposition of organic material situated beneath such a shale. Further, the bacterial action under such conditions would be continuous, as the accumulation of toxic acidic products resulting from the decomposition would be impossible in such an alkaline medium. The result of such a decomposition would be the production of a reduction residue as the oxygen required for the vital processes of the bacteria would be obtained from the decomposing material itself. Lastly, as the shale is impermeable, the clay being deflocculated in the alkaline solution, the products formed under such conditions would be prevented from escaping. The conditions imposed by the presence of the alkaline shales are, therefore, such as would be necessary if petroleum had resulted from the bacterial decomposition of organic matter.

The Bacterial Decomposition of Organic Matter under a Layer of Sodium Clay.

The bacterial decomposition of some types of organic matter under a layer of sodium clay has been dealt with previously.[11] The primary objects of the experiments discussed in that paper were to determine whether the alkaline anærobic conditions produced by a layer containing sodium clay would be suitable for the bacterial decomposition of organic matter situated beneath such a layer and, if decomposition took place, would the products tend to resemble members of the bituminous coal series.

The following conclusions were reached as the result of those experiments :—

(1) The conditions provided by the presence of sodium clay are suitable for the continuous bacterial decomposition of organic matter situated beneath it.

[11] E. McK. Taylor, "The Decomposition of Vegetable Matter under Soils containing Calcium and Sodium as Replaceable Bases," *Fuel*, 1928, **6**, 359-367.

(2) Sugar and starches decomposed under such a layer yield products which were entirely gaseous, the gas accumulating under the sodium clay being principally methane.

(3) Cellulose can be decomposed by bacteria under these conditions, the products again being gaseous.

(4) Acid peat could be decomposed by bacteria under a sodium clay. The alkali-soluble "humus" was extracted by the alkaline solution and completely broken down. The lignin was also attacked.

(5) Leaves could be decomposed under a sodium clay layer. Analysis showed that oxygen had been eliminated from the material, a process that has taken place in coal formation. The lignin was attacked and developed a characteristic fusain appearance.

(6) The gases generated during the decomposition accumulated under pressure under the impermeable sodium clay. Carbon dioxide, although it must have been formed as the result of the bacterial activity, was not present in the accumulated gas. This was due to its absorption by the dilute solution of sodium hydroxide formed by the hydrolysis of the sodium clay. The gas accumulating was principally methane.

From the point of view of the effect of sodium clay on the genesis of petroleum, the most important conclusions derived from the above experiments were :—(*a*) That continuous bacterial decomposition of organic matter could take place under a sodium clay roof; (*b*) that the roof was impermeable so that the gas accumulated under pressure; and (*c*) that the absorption of carbon dioxide takes place by the sodium hydroxide leaving a residue which is practically pure methane.

From the point of view of petroleum formation, the decomposition of the oils and fats will be probably of more importance than the decomposition of the materials carried out in the investigations on coal formation. It was decided, therefore, to study the decomposition of oils, fats and related substances under such conditions. The material to be submitted to bacterial decomposition was distributed through a sand layer at the bottom of a beaker, and the sand layer moistened and inoculated with a soil suspension. A roof containing hydrolysing sodium clay was deposited on the sand and a layer of water maintained on the top of the roof. The beaker was then incubated at 30° C. The general arrangement and the development and accumulation of the gas under pressure is shown in Fig. I. The following substances were submitted to decomposition :—(*a*) Glycerol, (*b*) triacetin, (*c*) triolein, (*d*) tributyrin, (*e*) cod liver oil, (*f*) stearin,

(*g*) stearic acid, (*h*) palmitic acid, (*k*) sodium stearate. Fig. I is the decomposition of cod liver oil and is typical of the bacterial decompositions under these conditions.

FIG. I.

Bacterial Decomposition of Cod Liver Oil under a Layer of Sodium Clay.

While final results of these experiments cannot yet be given as the decompositions are still actively proceeding, certain interesting results having a direct bearing on the genesis of petroleum have been obtained. The observations so far made will be briefly described.

DECOMPOSITION OF GLYCEROL.

Glycerol on decomposition under the sodium clay yields an entirely gaseous residue of methane. The decomposition is very rapid. The oxygen of the glycerol has probably been eliminated as carbon dioxide and absorbed in the alkaline solution as was the case in the decomposition of sugars, starches, etc., previously recorded. The occurrence of glycerol in all fats and its decomposition to yield a methane residue under a sodium clay would account satisfactorily for the almost universal association of gas with oil.

DECOMPOSITION OF TRIACETIN.

The decomposition of triacetin results in the formation of methane alone[12]. The gas accumulates in the characterististic manner shown in Fig. I. The sand layer becomes black during the decomposition owing to the formation of ferrous sulphide. This is a further indication of the anærobic conditions imposed by the layer of sodium clay.

DECOMPOSITION OF TRIBUTYRIN.

The decomposition of tributyrin is similar to that of triacetin. Gaseous paraffins alone appear to be produced, the gases accumulating under the impermeable roof. This type of decomposition is entirely different to that taking place under a roof of calcium clay. Under a roof of calcium clay, butyric acid was produced and at the same time the gases formed do not accumulate but pass through the roof to the outside atmosphere. The conditions under a calcium clay are not such as to yield reduction residues nor are they suitable for gas accumulation.

DECOMPOSITION OF MIXED FATS AS IN COD LIVER OIL.

This decomposition is still proceeding. It is apparently taking a similar course to those of triacetin and tributyrin. Characteristic gas accumulation is taking place and the sand layer has become black. A mixture of the higher fats is, therefore, capable of bacterial decomposition under these conditions.

DECOMPOSITION OF STEARIC AND PALMITIC ACIDS.

The commencement of the decomposition in these cases was considerably delayed. Little change was noted for a period of about three months. At the end of this period, the first indication of bacterial activity was the production of ferrous sulphide in the sand layer which turned black. This was followed by a slow production of gas, the accumulation of which at the end of eleven

[12] E. McK. Taylor, "Base Exchange and the Formation of Coal," *Nature*, 1928, **121**, 789-790.

months was similar to that in the case of cod liver oil. The decomposition is still proceeding. The decomposition of stearic and palmitic acids is particularly important as it shows that acid substances can be decomposed by bacteria under a sodium clay roof. This appears to be a type of decomposition not noted previously as acid substances produced by the accumulation of residues of bacterial decomposition are usually regarded as inhibiting further bacterial action.

The observations recorded in the foregoing experiments are important as they indicate the following conclusions:—

(1) Oils, fats and allied substances can be decomposed by bacteria under the conditions imposed by a sodium clay roof.

(2) If the oils and fats are decomposed previously under ærobic conditions resulting in the formation of fatty acids, the presence of a sodium clay roof affords conditions suitable for the further bacterial decomposition of these acid substances and the decomposition will be carried out under anærobic conditions yielding reduction residues as indicated by the formation of ferrous sulphide and methane. The accumulation of organic material in an acid form does not now present difficulties in accounting for its further bacterial decomposition since the discovery of this type of bacterial action.

(3) Glycerol is readily decomposed yielding methane. As glycerol is a constituent of all fats, its decomposition, following hydrolysis of the fat, would account for the universal association of methane with petroleum.

(4) A naturally occurring mixture of oils and fats decomposes in a similar manner to the pure substances.

THE PROBABLE MODE OF DECOMPOSITION OF THE FATS AND OILS AND ITS BEARING ON THE COMPOSITION OF PETROLEUM.

From the results of the decomposition of glycerol and the simple fats, triacetin and tributyrin, it is possible to put forward a tentative explanation of the mode of decomposition of oils and fats under a sodium clay layer. As glycerol on decomposition yields methane as the residual gas, and as methane is also produced in the case of the decomposition of triacetin and tributyrin, the most satisfactory explanation seems to be that the glycerol in the fat is that portion responsible for the production of methane on decomposition. This would leave the fatty acid for further decomposition. Under the reducing conditions imposed, it is suggested that this would result in the reduction of the acid to a corresponding paraffin.

The value of the suggested method of decomposition of the fats is that it affords a reasonable explanation of the presence of the various constituents and of the variations in the composition of petroleum. The natural oils and fats can be regarded as mixtures in varying proportions of the triglycerides. The triglycerides themselves may be either simple or mixed according to the fatty acids present. If then these naturally occurring mixtures of triglycerides were decomposed as suggested, it would be expected that one constant product—methane—would be formed as glycerol is a common constituent of all the glycerides. The residue after the decomposition of the glycerol would be either a mixture of fatty acids formed from the mixture of simple triglycerides or a mixture of fatty acids formed from the mixed triglycerides. In either case, a mixture of fatty acids would be formed. The decomposition of this mixture under the alkaline anærobic conditions would result in a mixture of the corresponding paraffins. The suggested mechanism of the decomposition would, therefore, account for the constant constituent methane, the individual components of the petroleum, and the variations in composition according to the nature of the fatty acids and the proportions in which they were originally present. An investigation on these lines is now being conducted.

Application of the Results to the Genesis of Petroleum.

It has been stated[13] that "In seeking the origin of petroleum one must not introduce extraordinary theories for its occasional occurrence amongst unusual surroundings, but consider only such views as will account for its extensive production and wide distribution by common processes of Nature." It has been further stated that primary petroleum deposits are confined to sedimentary strata and that the material from which the petroleum has been formed has been deposited with the sediment in water, and generally in salt water, as proved by the remains of a salt water fauna and flora. The suggestion contained in the above statements is that the conditions necessary for petroleum formation are to be found in sedimentary rocks deposited in salt water and that these conditions must be found whenever a sediment is deposited in salt water to account for the wide distribution of petroleum. It has been shown that when clay comes in contact with salt water base exchange takes place and sodium clay is formed. This reaction occurs whenever sediments are being formed under marine, estuarine and deltaic conditions. Further, an examination of sediments

[13] A. Beeby Thompson, "Oil Field Exploration and Development," vol. I., p. 19, London, 1925.

deposited under these conditions and ranging in age from the Cambrian to recent has been made, and it has been shown that base exchange with the clay portions of the sediments has been taking place throughout this period. Base exchange is, therefore, one of the commonest processes of nature, and has occurred since the earliest sedimentary rocks were formed under marine conditions. A second process of common occurrence in sedimentary rocks is that the material composing them has usually been subjected to the action of fresh water subsequent to deposition. This has been shown by the determination of the pH values. Sodium chloride is usually absent and they are frequently alkaline, indicating that hydrolysis in fresh water must have taken place. The production of sodium clay by base exchange and the hydrolysis of the sodium clay in fresh water are among the commonest processes of nature associated with the formation of sedimentary strata and especially with the formation of shales and clays under marine, estuarine and deltaic conditions.

Petroleum-bearing strata are invariably overlaid by impervious beds, usually shales. Can these shales impose conditions on decomposing organic matter beneath such as would result in petroleum formation? It has been shown in the examination of a number of specimens of the shale that the characteristic constituent is a sodium clay, and that this sodium clay has undergone hydrolysis in fresh water. It has been shown also that this hydrolysis has had two main results: (*a*) the production of an alkaline solution containing sodium hydroxide, and (*b*) the production of impermeability in the shale containing the sodium clay. The production of impermeability in the shale has been shown to have two consequences: (1) the organic matter in strata beneath it has been under anærobic conditions, and (2) the strata beneath the sodium clay has been sealed so that no products of decomposition could escape so long as the strata remained undisturbed. It has been further shown that the medium produced by the hydrolysis of the sodium clay is such as to favour bacterial action under anærobic conditions and that the result of this bacterial action is the formation of reduction products. It has also been shown that the bacterial action is continuous and not inhibited by the accumulation of toxic acidic products, since these are either neutralised or completely decomposed in the medium. Taking into consideration the geological evidence and the chemical, physical and biological properties of the strata in which petroleum occurs it is suggested that petroleum has resulted from the bacterial decomposition of organic matter, probably oils and fats, under the alkaline anærobic conditions provided by shales containing sodium clay which has been subjected to hydrolysis in fresh water. The suggestion involves the assumption that all shales

overlying oil-bearing strata have undergone base exchange and hydrolysis. From the geological evidence the majority of the shales have undergone base exchange. It remains to be demonstrated that they have also been submitted to the second process—hydrolysis. It is hoped to collect and examine a large series of shales to determine whether alkalinity resulting from hydrolysis is a universal characteristic.

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Oilfield Practice in 1927.*

By A. Beeby Thompson, O.B.E., M.I.Mech.E., M.Inst.M.M., F.G.S. (Member).

The year 1927 will not only be remembered for the remarkable advances in oilfield technique, but for the startling discoveries of new sources of oil supply in the U.S.A. A jump of 235,000,000 barrels in the production of the United States made the modest increases of output of other countries appear insignificant. Venezuela nearly compensated for the fall of the Mexican output, and other noteworthy improvements occurred in the production of Russia, Persia, Dutch East Indies, Colombia and Peru; whilst in Irak definite proof of the existence of large oilfields was forthcoming.

Although new production methods played an important part in swelling the oil production of the world, equally valuable innovations were introduced into geological examinations, and striking reforms were made in drilling processes. Geo-physical surveys led to the location of many concealed salt domes, and by confirming the result of surface observations enabled prospectors to locate their test wells with greater confidence than previously. Drilling methods were so vastly improved that depths of 5000 to 7000 ft. occasioned no concern, and in one field the Ventura Avenue, California, 7000-ft. wells costing about $150,000 were being regularly completed in the face of great technical difficulties caused by successive water exclusions and high-pressure gas problems.

As might be expected, deeper drilling compelled producers to modify old-time methods of production. An effective control of the flow from deep wells was imposed not only by the dangers attending the blow-out of high-pressure wells, but by the heavy losses producers sustained if the wells were destroyed. Elaborate provision is now made to ensure the control of deep, high-pressure wells which once out of hand may spell disaster to a field. Surface columns are cemented and concreted in place and each water string is cemented independently. Gas sources are mudded off, and heavy muds weighing up to 80 lb. per cu. ft. are used to prevent eruptions until all surface fittings have been fixed in readiness for regulated flow. Massive steel fittings designed to stand pressures of 2500 lb. per sq. in. are attached to the casing head in such a way that flow

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nipples can be readily renewed or altered to suit the condition of the well.

The dangers that attend the loss of control of a deep well have been witnessed in a number of cases in U.S.A., Mexico, Venezuela and Rumania, where casing and surface fittings have been torn to shreds and oft-times craters formed. One of the most serious and difficult tasks ever imposed on oilfield operators was the blow-out of one of the wells in the Maracaibo Lake, where the water was 34 ft. deep. Before the flow could be controlled large stretches of the lake were covered with floating oil, the gas eventually ignited and was only extinguished by explosives after several futile efforts, and a submarine crater 150 ft. deep was formed. Only after drilling a relief well 300 ft. away was it possible to get the floats over the site and mud off the offending bore, a task which occupied altogether about two months.

Control by flow nipples is now customary in most fields where high pressures are encountered. They are now in general use in Russia and Rumania, where their early introduction was viewed with serious misgivings owing to the loose nature of the sands from which the oil is derived. The sand contents are kept to determined proportions by control of back pressure.

A more general recognition of the value of gas as a propulsion agent has stimulated interest in all methods designed to reduce the gas-oil ratio of wells. Not merely does gas supply the power for expelling the contents of sand, but it is now appreciated that the viscosity of the oil is reduced by gas in solution, thus facilitating the travel of oil in the sands. Attempts have been made by well-wishing, conservation supporters to secure the fixing of a maximum gas-oil ratio in certain fields. Without imposing irritating hindrances and causing certain injury, it is unlikely that any useful ruling can be made unless fields are developed as a unit on some co-operative plan. There must necessarily be a larger proportion of gas produced with oil from high points on domes or anticlines than down the flanks; indeed, in some cases gas alone will escape if the output is sufficiently controlled. At high points on structures the flow for a time may be merely a spray of oil with gas.

Considerable attention has been paid to the unit development of oilfields, the ultimate advantages of which have been so often alluded to in literature.

Endeavours to check irrational exploitation of structures are usually frustrated by the frenzied activities of operators intent on scoring off their neighbours in fields where leases are held on small acreages indiscriminately scattered over a productive area. Although the penalty of haste and reckless exploitation is so clearly foreseen, no practical way has hitherto been found of generally inducing

competitors to embark on the development of a pool on rational and scientific lines. Limestone fields are naturally best suited to unit control, as the reservoir rock is more continuous than arenaceous fields, and both the gas areas and the edge water belt can be closely determined and the intermediate zone can be so exploited that the ascending edge water is regulated to ensure exhaustion of the oil stratum, and the maintenance of an acceptable gas-oil ratio. This plan is being carried out on the Maidan-i-Naftun field in Persia, where the oil contents of the pool have been closely estimated by numerous test bores, as was the case in some Mexican pools.

Economists are incessantly referring to the need for conserving natural oil resources, so easily and cheaply won before the potential energy is dissipated. The co-operative or unit development of oil pools is recognised by all as the only way of preventing the evils of over-drilling and over-producing, with its attendant abuses and waste of man-power and materials.

With our present knowledge it seems sheer madness to pursue the policy of leaving great oil reserves to the merciless handling of land grabbers who have no respect for the laws and customs dictating the policy of the regular and cautious oilfield operator. Cajoled by promises or gifts, owners of land in the vicinity of oil discoveries grant leases which either become the prey of speculators or repeatedly change hands at enhanced values and terms which can yield no adequate return to proper development. If the great oil pools of the U.S.A. could be systematically prospected, and then developed so as to ensure the gas being retained in the elevated points whilst the flanks between the gas and water lines were exploited with a limited number of carefully spaced wells, all holders of leases on the structure could share in returns on an equitable scale determined by experts with eventual advantage to all concerned and the industry at large.

Regulated drilling by mutual agreement is in force on some fields where two or more large concerns control the acreage, but the main objection to unit development lies in the difficulty of arranging an equitable allocation of the oil and gas drawn from a controlled structure where little is known concerning the distribution of fluids and so the potential values at the time leases are acquired. As a rule, pro-rationing of production by flow tests of wells over a limited period gives no safe figures of their regular yield, and many maintain that shut-in producers never recover their original capacity.

The year 1927 will be remembered, especially by American oilfield operators, for the great advances in the use of air lift. World-wide notice was attracted to the process in 1927 on account

of the unprecedented success which attended its employment in the Seminole field of Oklahoma and the results achieved by its use in the fields of West Texas and California. No more ideal conditions for its employment could be imagined than those existing at Seminole, where a highly porous oil-saturated formation yielded up its contents freely. Once the short-lived period of natural flow came to an end, due to the limited volumes of gas present, air or gas could be applied whilst the static head of the oil was very high. It was thus possible with small submergence, low pressure and small volume of air or gas, to lift the oil at a rate often far in excess of the original natural flow. Mainly by means of gas lift the Seminole field with a productive area of 20,000 acres yielded within 21 months of discovery an output of 15,000,000 bls. of oil per month. In 1927 the output of oil was 136,000,000 bls., equal to 10·7 per cent. of the world's production, and the flood of oil was largely responsible for the depression of the oil market. When it is considered that such a small acreage can be made to produce in one year a volume of oil in excess of all oil-producing countries in the world except U.S.A., the full significance of modern oilfield technique will be appreciated.

At one period in 1927 the output of oil by air-gas lift plants at Seminole represented 67 per cent. of the field's production and 11 per cent. of the daily average of the United States. One company had 250 compressors at work, representing a combined horse-power of about 28,000.

Extensive experiments have been undertaken to ascertain the most suitable ways of operating wells with air-gas lift to secure the best results, and much has been written upon the theoretical aspect of the case. As might be expected, no very useful formulæ can be framed when there are so many variables, and generally the best arrangement can only be found by actual trial in each well. Extended experience has, however, indicated the lines on which appliances should be designed for coping with different conditions.

Several pertinent questions have been exercising the minds of producers, including that of fixing the limits when air-gas lift should be supplanted by others systems of production. With the progress of depletion the rock pressure falls, and with it the static level of oil in the wells. The highest efficiencies are obtained when it is possible to obtain a suitable submergence ratio, which is dependent upon depth, and a minimum lift. As the level of fluid falls, with consequent increased lift, the submergence decreases until at length a point is reached where efficiency falls off greatly. Lower pressures are needed but larger volumes of air or gas are required to induce a discharge, and in ordinary circumstances the air lift would be replaced by pumps. Air-gas lifts are, however,

being kept in operation in deep wells long after their employment would have been discarded under ordinary circumstances, on account of the difficulties attending pumping when the wells are crooked and floating sand may be present. Constant breakage of rods, wearing of tubing and pulling for replacement of parts becomes such a source of expense with pumps that the air-lift is often continued to a stage when the efficiency is absurdly low. Operators have also stressed the question of hazard in the frequent abstraction and insertion of long strings of tubing. The fall of tubing in a deep well may entail long and expensive fishing operations and serious loss of production. These circumstances have induced operators to pay attention to intermittent air-lift operation which is comparable with the old process of stop-cocking. At arranged intervals air or gas is admitted suddenly and for a fixed period to the wells, and the accumulated fluid is expelled. Each discharge partakes of the nature of the initial flow of an air lift; that is, a discharge of fluid is followed progressively by a more and more violent expulsion of ærated fluid, until there is a final ejection of gas air on an almost explosive scale.

As a general rule, when the conditions are normal, air or gas is introduced into the annular space between the oil string and a properly proportioned inner flow pipe, the depth of which is arranged to give the necessary submergence. From time to time as the level of fluid falls the pipe is lowered, but it must not be lowered further than the top perforations or screens of the oil string. The working pressure balances the fluid pressure with allowance for friction, and just enough air is admitted to cause a flow to suit the particular nature of the well. By carefuly adjustment of the position of the flow pipe and the quantity of air admitted, the gas-oil ratio can be cut down to give the maximum working efficiency or, alternatively, the maximum output.

A more useful method is to have two strings of tubing and lead the gas through the annular space between the two whilst using the inner as a flow pipe. Only when the oil string is of large diameter can this course be adopted, but it has the advantage of permitting the air to be admitted at a much lower point, irrespective of the position in the casing of the perforations, which in California often reach 500 to 700 ft.

Some of the early tests in Rumania failed when air was admitted between the casing and the tubing, due to the formation of a sand plug which could not be cleared, whereas with a double tubed well it is easy to clear away sand accumulations.

When the difference between static and working oil levels is very considerable in deep wells very high starting pressures are often necessary. This has been overcome in California by various

devices, some of which admit air or gas initially at higher points. The "Surging," "Impulse," or "Rocking" method, as it is variously termed, is, however, largely practised, whereby a combination of piping and valves gas can be alternately admitted into the top of flow pipe and into the annular space.

Many wells have been fitted so that the fluid flows between the casing and a central pipe through which the air or gas is introduced at the proper depth. The objections to this course are severalfold. Firstly, the annular chamber presents a much greater surface and, consequently, greater frictional resistance, further accentuated by the circumstance that the tubing is never centrally located and is in contact with the casing sides at some points; secondly, when water is mingled with the oil the aerated mixture may cause corrosion, which is a serious matter when taking place in casing but is of comparatively small concern in tubes which can be replaced. In some Kansas wells tubing had to be replaced every 60 days, and in one well when the liquid was flowed in this way the 5 3/16 in. casing had to be replaced every five months. When it is simply a matter of making a high fluid-level well flow, as was the case in some of the wells of Texas and Oklahoma, the simplest and best plan to extract large volumes was to insert a small air-pipe and flow the oil from the casing.

Use has been made of graduated or tapered flow tubing with the idea of reducing the increasing velocity due to expansion of the gas or air as the surface is approached. Obviously, only by using a tube tapering from top to bottom could the velocity be kept within certain limits of constancy, and in practice the nearest approach to this end is attained by enlarging the eduction pipe at intervals. This is, consequently, only an imperfect device, and in any case the limits of size are controlled by the diameter of the oil string in wells. This method has proved effective in some very low-level wells by using large volumes of air.

Users of gas lift have met with emulsion troubles in some wells where water is present. Occasionally it has been necessary to replace the gas lift by other processes of recovery, where very refractory emulsions have been formed, but often modifications in the method of employing gas lift will improve matters. The emulsions are often destroyed by introducing Tret-o-lite or other products to the flow pipe well beyond the point of delivery where no further intense agitation is likely to occur. Reference is also made to the difficulties of employing air lift when the supply of gas falls off. The employment of air or other gases dilutes the natural gas so much that gas-gasoline recovery plant suffers to an extent that enforces a change. In one or two cases dry or treated gas has been piped a considerable distance to fields for gas-lift purposes,

and it is likely that this procedure will be extended much more in the future.

The re-cycling of gas for gas-lift plants has naturally led to a considerable increase in the number of gas-gasoline installations. By employing a closed circuit and gas traps from which only excess gas is allowed to escape, and introducing on the pressure side condensers or absorbers the gasoline contents of the gas can be abstracted. It is largely for this reason that preference is given to gas for lifting purposes. No general agreement has been reached as to whether the use of gas lift causes any reduction of gasoline, recoverable from the oil at the refinery. The result varies with different oils, but there is a belief that more light products of oil are saved than would be the case in the normal transportation of untopped light crudes to the refineries.

A great deal has been written about the efficiencies of air-gas lift plants, but the conditions are too variable and changeable to generalise on this subject. When an installation has been paid for by output of oil within 48 hours of being put in operation it is foolish to argue about efficiencies. In most cases the process affords the only means of extracting oil at a high rate, and under favourable conditions the cost of the plant is recovered in quick time. Gas-engine-driven compressors naturally keep power costs to a minimum, but the conveniences of electric power or steam often lead to the use of those sources of power regardless of the higher cost.

As soon as operators find that the lift can be profitably replaced by another system, with due regard to all sides of the question, they will naturally make the change. American operators have learnt what the writer has found elsewhere, that a system of extraction that continues without intermission 24 hours daily and 365 days a year is difficult to equal, however high the momentary efficiency of alternative processes.

Actual figures mean little unless all the facts are known. Mention has been made by an American engineer of the use of air lift at Cat Canyon, California, where two wells were producing about 300 bls. a day with 330,000 cub. ft. of air from a 2,800-ft. sand with 475 lb. air pressure. The oil of 10° to 12° A.P.I. gravity was too viscous to produce normally by other means, but air heated to 190° F. gave the above results at a cost of 14 cents bl. against 45 cents bl. for a pump. In the Rosecrans field, California, the cost of air-gas lift was 23 cents per bl. of production against 62 cents per bl. for pumping due to the need of keeping a pulling gang at each well. In the Seminole field, where the gas ratio was low, from 400,000 to 1,200,000 cub. ft. of gas per well was used with an average of about 800,000 cub. ft. Generally 1200 to 1500 cub. ft. of gas per bl. of

oil was used for lifting from 3800 to 4500 ft. wells with working pressures around 200 to 300 lb. per sq. in. Air-lift installations cost complete about $20,000 per well. In California installations cost between $15 and $25 per 1000 cub. ft. gas per day capacity.

Compression costs in U.S.A. have been put at 3 cents to 5 cents per 1000 cub. ft. for large compressor stations of, say, 6,000,000 cub. ft. day, and 5 to 8 cents per 1000 cub. ft. for smaller installations. A general figure for air lift has been given at 8 cents per bl. with allowance of 20 per cent. depreciation of plant in large installations, and about 12 cents. per bl. for small units. As power is the chief item of expense much depends upon the kind of motor used. It has been claimed that the cost of most gas-lift installations in California is often recovered within two to six months on account of the greater volume of oil raised and, consequently, the increased quantity of gasoline obtained from the gas which accompanies the oil.

The recovery of oilfield dregs has made little headway owing to the lack of encouragement following the low price of oil. Vacuum work has almost entirely been superseded by the reverse process of re-pressuring air or gas drive and flooding. Altered views on vacuum application have discouraged producers, especially as the value of gas-gasoline has fallen to such a low figure that the chief incentive for the use of the process has disappeared. The difficulties of maintaining a partial vacuum, which had to be constantly increased to ensure continuity of success, were very great and costly, especially as pumping troubles were increased and heavy inrushes of air took place when pulling the wells. Air or gas drives are more effective than vacuum, as a greater differential can be obtained and a re-pressuring proceeds due to absorption of air or gas by the oil.

Gas drives or pressure restoration schemes have been continued with varying success in a number of oilfields in U.S.A. Early efforts were mainly confined to fields where the yields of wells failed to give payable productions, but more recently efforts are being directed to the re-pressuring of areas during their real productive life. Perhaps the most important attempt to rejuvenate a field is being made in the Salt Creek field of Wyoming, where large acreage is controlled by a single company. Here the re-cycling process has been installed on a large scale whereby gas separated from the oil during production as well as casing head gas is deprived of its gasoline contents and then returned to the oil sands in wells specially arranged for its reception in two of the main sands. Some 30,000,000 cub. ft. of gas daily are said to be returned to the earth at a pressure averaging 140 lb. per sq. in. By a careful selection of intake wells and a suitable handling of those in production some 150 wells have had their yields considerably augmented. Experiments

are still in progress for improving a method the value of which has been demonstrated beyond question. The rock pressure at Salt Creek had fallen to about 50 lb. and the yields of wells was in the neighbourhood of tens of bls. a day, but in California gas has been introduced into sands where the rock pressure was 1500 lb. and the yield of wells in the nature of hundreds of bls. daily. Increased yields were obtained from nearby wells, but only prolonged tests will prove whether it will pay to force gas into strata against a high pressure, even if the process is a re-cycling one. Published results of a Marland test at Seal Beach, California, showed that gas was forced into an oil sand against a pressure of 1500 lb, and that neighbouring wells up structure gave up to a 50 per cent. increase in production. Variation in the position of intake well led to somewhat irregular changes in surrounding wells, but in all cases an improvement resulted. The engineers considered that not less than 1 bl. of oil per 495 cub. ft. of gas introduced could be attributed to the admission of gas. The increased gas yield represented about 80 per cent. of that output. From the figures given the increased production due to re-pressuring must have been about 3000 bls. per day for 1,500,000 cub. ft. of gas. Doubtless such a figure would not be sustained, as the chief improvement occurred during the first few months of air admission. Short-circuiting by air was found to introduce difficulties. It is believed that the methodical introduction of gas into down-structure wells might benefit gas-lift operations and possibly lead to a wider spacing of wells and consequently to reduced exploitation costs.

A gas drive was attempted on the Moreni field of Rumania, and a decided improvement was noted in neighbouring wells within a short time. Attempts at restoration of pressure at Bushtenari, Rumania, as might rather be expected in a field where several wells per acre were drilled, failed. Naturally, results of re-pressuring can hardly be expected to show in a short time unless very large volumes of gas are introduced. A simple calculation of past losses of gas will give some idea of the space that has to be filled before any useful pressure can be restored.

Experiments are being conducted to ascertain the relative merits of various gases as propulsion agents. Some argue that underground conditions do not admit of the requisite intimacy of contact to ensure absorption of gases and consider something of the nature of a drive occurs rather than a revivification of the oil. Both processes are probably at work, and those aiming at re-saturation of the oil are considering the use of other gases like CO_2, which is much more soluble than air or hydrocarbon gases. It is known that wet gases are more soluble than Methane and as a re-saturation agent are superior.

Original air drive work was undertaken in the Appalachian oil-fields, and C. R. Fettki has recently published figures concerning one of the earliest properties near Oil City, Pennsylvania, so tested. Since July, 1916, when a restoration of pressure by the Smith Dunn (Marietta) process was commenced, on account of the unprofitable character of the wells, some 100,000 bls. of oil have been recovered from 300 acres from a sand averaging 20 ft. thick. In 1927, 17 intake wells were receiving an average of 20,700 cub. ft. per well per day at 95 to 110 lb pressure, and the average daily yield of some 76 producing wells was 0·4 bls. compared with 0·1 bls. prior to the use of air.

Water drives or floodings of oil strata have been the subject of debates and experiments, but little has been done outside the old Bradford field, where the conditions are so favourable. Although natural water drives are in force in all limestone fields and in many sand structures, there is a disinclination to introduce water flushes owing to the lack of general knowledge concerning the behaviour of admitted water; and once flooded the further question of de-watering to recover further oil is a problem of some perplexity, as it is known that a large part of the oil contents still remain. Nevertheless, the subject is one kept prominently in mind by technologists, and research is constantly being undertaken on the value of selected salts known to assist in releasing oil from the sand grains. It has been shown that certain alkaline salts like caustic soda or sodium carbonate materially aid the liberation of oil from sands, but obviously cost is likely to prove a decisive factor against their use in most cases.

Hitherto water drives have been confined to fields where oil is confined to compact sands, and where movements are slow and several wells per acre have to be drilled to tap the flood of oil ahead of the water wave. Some have questioned whether any other field in U.S.A. offers equal prospects to Bradford, where drilling is easy and quick, water is present, the grade of oil is high, and the location is ideal for the disposal of products. Less cost would be involved in flooding unconsolidated sands or limestones judging by the effect of accidentally admitted water, but on the other hand the control of water once put into the sands would be a much more difficult matter.

The proposal has been made of introducing water to limestone domes if the edge water fails to keep pace with the process of oil and gas depletion. In the case of Mexico water followed the extraction of oil until total exhaustion in the great coastal belt fields. But in some fields the water does not replace the oil and gas abstracted, and if sufficient water were admitted much oil might be displaced and forced into high points of structures.

Much attention has been paid to the ways and means of avoiding the paraffination of wells in regions where paraffin base oils are being produced. Further studies of the behaviour of wells and experimental work in the laboratory have proved that precipitation of the higher melting-point paraffins from crude oils is mainly due to a drop in temperature, but in a less degree to loss of volatile constituents. Whether oil flows naturally or is raised by pumps or other devices there is always some loss of heat by radiation and through expansion of gas, and the combined effect is to cause a separation of wax at some point when the critical temperature is reached during its ascent to the surface. It is chiefly on account of this loss of heat that paraffin is deposited over some distance of the piping or casing along some variable range intermediate between the base and the surface. Deposition does not necessarily cease in the well but may continue in the flow lines, especially in cold weather when the whole body of the oil will congeal if not heated.

The Panhandle oil of Texas has been one of the most refractory to deal with, but certain fields in Rumania yield oils nearly equally troublesome. Under controlled and continuous flow no damaging quantities of wax may be precipitated, but when unrestrained surging takes place and the eruptions are intermittent wax is often very freely deposited, and the casing or piping may be plugged in a short time, due to excessive loss of heat and to loss of volatile products. Any methods introduced to check this action will prove beneficial, the main object being to produce oil in a state as near as possible as when found in the earth. It is thought that the subterranean conditions rarely encourage the precipitation of solid paraffins in the oil-containing sand or limestone; on the other hand, dry-pumping leads to a surface incrustation on the face of the sands, which may partially or entirely shut off the influx of oil to the well. For this reason alone the oil-bearing formation should always be kept submerged.

Amongst the remedies being employed to deal with paraffin troubles, when circumstances render their prevention difficult or impossible, may be mentioned the use of solvents and heaters for dissolving and liquifying wax in the base of wells, and of scrapers for releasing wax from tubing or casing. Kerosine or gasoline, preferably gas-gasoline, are the solvents most commonly used. For general heating superheated steam, hot oil, chemicals and electric heaters are in use. Wells in Salt Creek and elsewhere have been cleared by pressing down the paraffin with tools and allowing a pressure of gas to accumulate beneath and blow out the contents. In other cases wells are being cheaply cleared of wax by blowing out the contents of the well with air or gas admitted in large volumes and at high pressure from a receiver. Occasionally

badly waxed sands are cleared by using a light explosive charge or scraping the face of the sand with reamers. The most favoured chemical mixture for heating wells is sodium hydroxide and aluminium filings. Paraffin can often be released and expelled by alternately shutting in the well to let the pressure mount up and suddenly relieving the pressure to allow the well to flow. It is thought that gas dissolved by the paraffin under pressure breaks down the cake and the heavy flow carries it away through the tubing.

Of general interest is the fact that the paraffin coating undoubtedly protects the pipes from corrosion where the water and gases are highly destructive through the presence of hydrogen sulphide.

Little recent progress has been made in mining for oil. The difficulties attending such operations are becoming appreciated more and more, and the low price of oil does not encourage experiments. Operations continue at Pechelbronn, Alsace, where 68,000 tons were recovered in 1927. Several tests are being made in Rumania with varying success. Work of a very important character undertaken at Campina, Rumania, was suspended on account, it is said, of water difficulties, but at several other places small productions of oil were obtained by galleries. Some interesting work is now in hand at Bushtenari, where the oil sands have a considerable dip and the oil is very light in density. As the oil of Bushtenari is accepted as the standard of quality, just as the Pennsylvanian oil in America, the prospects are hopeful if the not inconsiderable technical difficulties can be mastered.

Worthy of record is the fact that the Royalite No. 4 well in the Turner Valley field near Calgary, Canada, has continued to yield 500 bls. of light (72° Bé) oil daily as a spray, with some 17 m.m. to 20 m.m. cub. ft. of gas. No equally good wells have been struck so that it may have to be regarded as a freak. A number of deep wells are yielding moderate quantities of light oil as a spray with gas flows, but difficulties are found in keeping the wells from freezing due to the presence of moisture.

Arrangements have been made to pipe away more of the gas which is now being burnt, and operations are in hand, it is said, for returning gas to the earth and preserving it until wanted.

Considerable attention is now being given to the return of surplus gas to oilfields, and its conservation is at length being seriously entertained in many countries, and indeed may be officially enforced in some. On practically all oilfields plant is now installed for extracting the gasoline contents of casing head gas before its use as fuel or return to the ground. Absorption methods have practically replaced compression processes, owing to the lower costs of plant

and the production of a more stable product. Electric power is likewise extending in all fields where stability of production is assured. Elsewhere gas and oil engines are in general use for all kinds of purposes where formerly steam was employed at a cost in fuel several hundred per cent. above that of internal-combustion engines. A development of importance is the increasing use of high-speed gas-oil engines that are portable in character and require no foundations.

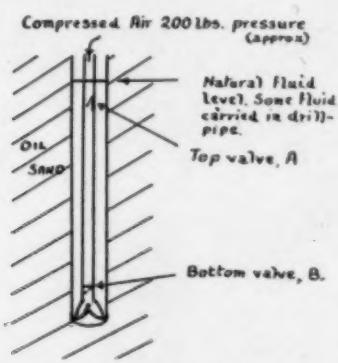
Another striking change is found in the general use of recording apparatus for nearly all field purposes. Automatic recorders are used for nearly all purposes where measurements are useful for checking consumption and reducing waste. More and more attention is likewise given to the evaporation problems by the use of suitable paints on tanks and other devices. The floating roof appears to be accepted as the most convenient way of reducing tank losses during storage.

Notes on New Methods of Drilling in California.*

By A. E. Cooke Corbet (Associate Member).

Dry Hole Drilling (Rotary).

This method is still in the experimental stage but has met with success in several instances. The plant is similar to the usual rotary outfit with the addition of an air compressor. In low-pressure formations the mud tends to kill the sand, so the idea was conceived to "drill in" a well, after final isolation, with its own fluid. To circulate this fluid and to clean and cool the bit two valves are necessary in the drill-pipe and compressed air is used. The diagram below illustrates this.


Compressed Air 200 lbs. pressure (approx)
Natural Fluid level. Some fluid carried in drill-pipe.
Oil Sand
Top valve, A
Bottom valve, B.

The bit and drill-pipe are run in in the usual way, drilling commences, and after a few minutes when the bit ceases cutting a shot of air is put in through the hose, kelly and drill-pipe. This passes out through valve B, expelling the fluid in the pipe. This air and fluid clear and cool off the bit, and the fluid level rises in the hole so that some of the fluid opens valve A and gravitates into the

* Paper received November 9th, 1928.

drill-pipe. Thus, cool and clean fluid is continually entering at A with every shot of air. A shot of air is put down every four minutes at about 200 lb pressure.

The valve A has to be adjusted as the hole goes down, and the best position for this valve will be slightly different under different conditions. A little experimenting readily finds where to locate valve A.

Periodically the drill-pipe is pulled out and the hole bailed clean. This method is supposed to be faster than cable tools and better. In one case a 70-barrel well was obtained where only a 15-barrel well was expected

Pneumatic Method of Drilling.

This method as yet has not proved a success. When perfected it is hoped that running in and out the hole to change bits will be eliminated. The idea is the same as the pneumatic hand drills used for tearing up roads, but instead of one knife there are four or five below the drill collar. To operate these knives it is necessary to have two air lines down the inside of the drill-pipe. Circulation is used in the usual manner. The air lines are made up at every stand. This method, however, is very much in the experimental stage and cannot be regarded as successful.

Doheny-Stone Hydraulic Feed Drill.

1. *Principle.*—A principal feature of the Doheny-Stone outfit is the hydraulic rotary table and the practical advantages that are possible with this type of table.

The increasing depths of wells automatically called for equipment that would stand more strain, and the tendency has been to make heavier the orthodox type of rotary outfit. The Doheny-Stone hydraulic feed rotary equipment has broken away from the conventional type of standard rotary draw-works and table and offers a more scientific means of drilling and operating a drilling well. The strength factor is amply provided for in this outfit and the smooth operation and compactability of the draw-works, the absence of noise and excessive vibration impress one immediately with the design of this unit.

2. *Brief Outline of Equipment.—Draw-works.*—The all-steel draw-works is a self-contained unit and rests on a steel bed-plate with all working parts enclosed. The compactness and absence of framing posts, chains, line shaft and countershaft make it convenient to move about and rig up. Six hoisting speeds are possible. Other

features are the friction clutch which will hold or hoist the load if the brakes fail, the equaliser built into the base plate, Timken roller bearings for the drum. A sand reel unit can be mounted directly over the drum and thus eliminate standard tool equipment.

Hydraulic Feed Table.—The rotary table is mounted upon hydraulic cylinders by which means it is possible to feed the drill-pipe while drilling with the greatest accuracy and positive control. The drill-pipe may be held, up or downward pressed applied to the bit; also any failure of the draw-works or engine is not so serious as with the usual type of draw-works, it being possible to move the pipe by the hydraulic, which is independent of the draw-works and power plant.

The table has a shaft drive through flexible couplings and Timken bearings are used wherever necessary, those in the table running in an oil bath. The smooth operation of the table reduces the friction element to a minimum.

No cast iron is used; all castings are of steel. The lifting capacity of the hydraulic cylinders range from 65 tons at 350 lb pressure to 150 tons at 800 lb pressure. This is ample for any emergency to pull or hold tension on the pipe; also there is less probability of parting a string of pipe with the table than by use of the draw-works, because the power exerted is at all times indicated to the driller by a gauge conveniently placed on the hydraulic manifold which the driller can control with great accuracy.

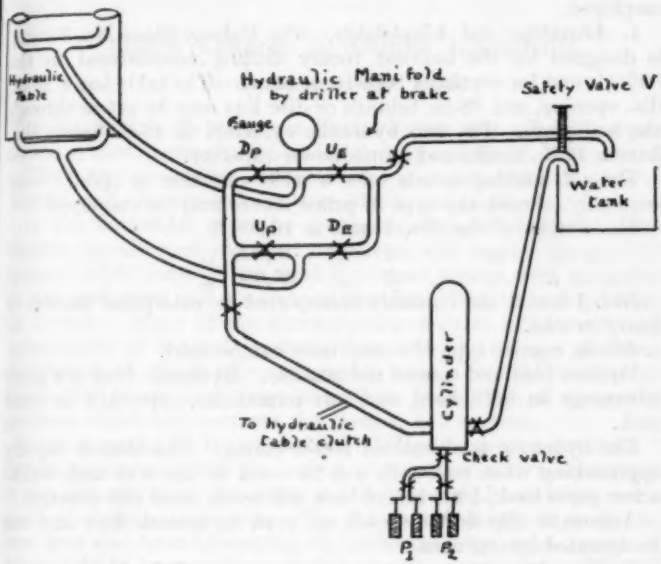
Another feature of this table is its adaptability for use in high gas pressure areas. The table is equipped with a stuffing box which, with the external flush tool joints and drill-pipe has proved very successful for drilling in high-pressure formation.

A device is attached to the table whereby one man can operate the slips. The square kelly can be used to drill with if desired, in which case the table is used as an ordinary rotary table; the hydraulic end not functioning.

Power Unit.—The electric drive for this outfit consists of a single direct connected 125 h.p., 440 volt, 50 cycle, 3 phase, variable speed induction motor. The 6 speed draw-works and exceptional pulling power of the hydraulic table give a reserve or emergency power not obtained in other rotary equipment.

3. *Method of Operation and Advantages.*—The draw-works operate in a similar manner to other draw-works. They are, however, more flexible, besides having the advantage of 6 speeds. The saving on chains is a very important factor, and shutdowns and breakages have been proved to be considerably less on this type of outfit in the field.

The diagram below illustrates the hydraulic rig up and principle of operation of the table, and is self-explanatory.



Hydraulic power is conserved in the cylinder and generated by the two pumps P1, P2. For upward pressure the valves U (pressure) and U (exhaust) are operated, and for downward pressure D (pressure) and D (exhaust) are operated. Pressure can be regulated positively and accurately by these valves and always indicated by the pressure gauge. The exhaust fluid goes to tank as shown in diagram. The valve at V is set as required—just as boiler blow off.

It is possible to use the Doheny-Stone Hydraulic Table in the same manner as other rotaries (not using hydraulic feature). The hydraulic feed, however, has the great advantage of positive feed, which does away with "hand" or "foot" methods of feeding the bit at the brake, and results in faster and straighter drilling. A maximum pull may be placed on stuck pipe without involving strain on the derrick and other rotary equipment, or endangering workers on the rig. In formations that squeeze it is possible to rotate up or down, which is an obvious advantage.

The various advantageous features apparently do not tend to increase running costs, which in fact appear to be rather lower, if anything, when compared with the usual rotary equipment employed.

4. *Advantages and Adaptability.*—The Doheny-Stone No. 3 outfit is designed for the heaviest rotary drilling encountered in the oilfields and for depths of 8000 ft. or more. The table has a 20-in. dia. opening, and 28-in. fishtails or disc bits may be set in through the bed plate. The two hydraulic cylinders of 15-in. inside dia. have a 42-in. stroke and ample power capacity.

The six hoisting speeds offer a wide variation in speed; consequently, almost any type of prime mover may be employed.

The weight of the No. 1 unit is 10,000 lb.
" " " " 2 " 18,000 "
" " " " 3 " 36,000 "

Nos. 1 and 2 can be easily transported on caterpillar trailers or heavy trucks.

All the regular type of rotary tools can be used.

Positive feed and control are possible. Hydraulic feed is a great advantage in both hard and soft formations, especially in hard rock.

The hydraulic feed enables better coring. The time is rapidly approaching when test wells will be cored all the way and, unlike a few years back, little loss of time will result from this practice.

Automatic slip device speeds up work on derrick floor and can be operated by one man.

Stuffing box device insures absolute control in high pressure formations.

The outfit is without framing posts and chains (except one small one to work cathead); hence easy to transport and rig up.

It is possible to release slips without raising drill-pipe or casing while same is being run into hole.

The ability to rotate and drill up through a cave is useful.

Flush Tool Joints.—The tool joint is a double male nipple with a tapered two-step Acme thread pin on each end. The Acme-thread is milled in each upset end of the drill-pipe. Tool joints are placed between each length of drill-pipe and the outside diameter is the same for pipe and tool joint, which feature makes all connexions flush and allows movement of the drill-pipe through a packed control head.

Among the advantages of using flush drill-pipe are wash-over jobs, caving formations, less wear on casing, etc.

In Ventura, where conditions are exceptionally difficult, this type of drill-pipe has stood up as well as the orthodox type of drill-pipe.

Eighth Congres de Chimie Industrielle.

Strasbourg—July 1928.

The Institution of Petroleum Technologists was officially represented at the Congress by Dr. A. E. Dunstan and Mr. M. E. Hubbard.

There was a very full attendance of scientists from all parts of Europe, and the proceedings were highly successful.

It was noticeable that the communications dealing with combustible liquids were the most numerous, and caused the greatest interest, while some of the most important papers were presented by the professors and students of the Ecole Nationale Supérieure du Petrole. Many of the communications dealt rather with the examination of finished products than with the diverse problems of refining, of which there is greater need. Nevertheless, these papers will be of great value during the elucidation of the many problems which still confront the chemist and engineer.

In the paper by M. Hugel, entitled "L'Hydrogenation des Brais," the author investigates the effect of pressure and temperature on the acid tar from petroleum in the presence of a catalyst composed of sodium hydroxide. The tar from kerosine is easier to treat than that from lubricating oil, whilst the latter gives a product rich in volatile hydrocarbons, and the former gives greater yields of lubricating oils.

G. D. Bengough, in his account of "Recent Developments in the Study of Corrosion," states that corrosion is not entirely a question of electro-chemical phenomena, but is due to some extent to oxygen acting as a cathode depolariser. The work stresses the importance of the study of corrosion problems, particularly in connexion with the refining of petroleum.

In a communication entitled "Hydrogenation under Pressure," M. Ipatieff has studied the various factors which govern catalysis when applied to the conversion of coal and other fuels into lighter and more volatile products; while in a paper entitled "Petroleum —Science and Industry's Raw Material," M. Pineau has enumerated the applications of the products resulting from the refining of crude petroleum.

The most interesting point of M. Darmois' paper on "The Cracking of Petroleum with Various Catalysts," was the description of a method of determining the quantities of saturated and cyclic compounds present in a mixture of these two substances. It

consists of measuring the index of refraction, using two widely distant rays of the spectrum.

In the "Preparation of Pure Hydrocarbons," M. Klepper has described a method and apparatus for the fractionation of small quantities of spirit (*circa* 20 ccs.), the identification of the fractions being carried out by means of determinations of refractive index.

M. Iselin's paper on "Vapour Tensions and Fractional Distillation of Lubricating Oils" consisted of a description of research—firstly, on vapour tensions of mineral lubricating oils from the point of view of inflammability and cracking, and secondly, on a method of analysing mineral lubricating oils by means of fractional distillation using vacuum.

"The Optical Properties of Mineral Oils" were dealt with by M. M. Vellinger, while M. A. Jeufroy contributed "Studies on the Ignition Temperatures of Hydrocarbons." In the latter it was observed that saturated hydrocarbons had a greater inflammability than those of the benzene series.

"Studies of the Pyrogenation of Mineral Oils" was contributed by M. C. Dixmier, who makes the interesting statement that the adherent properties of deposits formed by heat treatment varied with various oils.

M. M. van Rysselberge submitted a paper entitled "A Contribution to the Study of the Oxidation of Mineral Oils." This paper dealt in the first part with transformer oils, while the second correlated ease of oxidation with the degree of refining of mineral oils.

M. M. Ribou dealt with the "Compounds of Mercury with Olefine Hydrocarbons and their Employment in the Analysis of Hydrocarbons"; and the "Action of Concentrated Sulphuric Acid on Asphalt" was contributed by M. Stoenesco. Visits to the National School of Petroleum and to the works at Pechelbronn terminated a highly successful congress.

W. H. T.

REVIEWS.

The Geology of Petroleum and Natural Gas. By Ernest Raymond Lilley, Sc.D.

This is an ambitious book of 500 pages, dealing not only with principles but affording a great deal of detailed and useful information. It is evidently the result of a great deal of reading of scientific treatises and papers, but there is also a distinct practical side, and it must be admitted that it is on this practical side that the book is most successful. There are many maps and sections of American oilfields which are most valuable and instructive, and short histories of initial wells in some of those fields are given. Some of the maps, however, have had to be reduced to such a small scale for reproduction that the details are not always clear without the aid of a magnifying-glass, but still they will prove of great value to the student of the subject, and even to experienced geologists. The chapter upon salt domes contains a fund of information of interest to the geologist, even though no very definite conclusions are arrived at.

Some of the chapters read somewhat as if they were University lectures slightly written up and extended, but they are written in an impartial and judicial way, not attempting to solve all the questions under discussion, but presenting the views of different authors succinctly, and giving some of the main points of evidence in favour of different theories.

In matters dealing with countries other than the United States, the author has obviously had to rely to a great extent upon second-hand evidence, and it is not to be wondered that a certain number of errors have crept in. For instance, he states that in naphthenic oils the petrol fraction is almost always low. This may apply generally in the United States, but it is certainly not true of all other countries. Again, Albertite is called a pyrobitumen, and thus classed with elaterites as distinguished from the asphaltites, when there is really no difference between a Gilsonite and Albertite, except in degree of inspissation. The statement on page 59 that solfataric waters of magmatic origin are present in Trinidad, and have had effects in producing the asphalt of the pitch lake, is too far-fetched to find acceptance with any geologist acquainted with the ground, and the statement that the oldest and lightest oils of Trinidad come from the Cretaceous beds might cause misunderstanding, such oils being filtered petroleum of Tertiary age. However, errors such as the few examples given above are not the fault of the author, but of publications which he has consulted.

It is hardly fair to the pioneers of geo-physical exploration work in Europe to state, as is done on page 495, that "The reputations of both the seismograph and the torsion balance as tools for exploration for oil rest solely at the present time upon their success in the Gulf Coast territory of Texas and Louisiana." Years before either seismograph or torsion balance were used for geological exploration work in America, oilfields had been discovered and proved with the help of the torsion balance in Central Europe.

The book has another interest in showing the advance that has been made within recent years in general theories with regard to petroleum and its origin. Professor Lilley pronounces quite conclusively upon the genetical relation between coal, oil and kerogen, though not excluding the possibility of some animal matter having possibly contributed in the formation of petroleum. As regards kerogen, he is obviously inclined to regard it as a source of petroleum or an intermediate stage between vegetable matter and petroleum, a view held by a number of authors, though difficult to reconcile with the facts. The statement, however, that the kerogen of oilshales can pass into torbanitic developments can hardly be allowed to pass.

In dealing with earth movements, the author expounds some very interesting and original views which are worth very serious consideration, though the keeping of faulting and folding separate, as if possibly unrelated, may be a shock to some of his readers. There are many other points in connection with the relation of oil to gas, the migration and filtration of oils and the effects of surface tension, in which new ideas are expounded carefully and judicially. The author's views may not always be accepted, but they are certainly deserving of thorough consideration.

The book as a whole, though admittedly chiefly a summing up of the present knowledge of the day, and pointing to much research that has yet to be done, is a very good comprehensive account of oilfield exploration and development, both in theory and practice. It is a book to buy and keep for reference, especially with regard to petroleum phenomena in the United States of America. E. H. CUNNINGHAM CRAIG.

PETROLEUM DEVELOPMENT AND TECHNOLOGY IN 1927. The American Institute of Mining and Metallurgical Engineers. New York, 1928. Pp. 844. $6.00

This is the third volume of the series of Annual Reports of the A.I.M.E. and consists of papers read before the Petroleum Division at Fort Worth, Texas, in October, 1927, and at New York in February, 1928. The discussions on the various papers are also included.

The work is divided into six main sections, each of which is divided into chapters on separate subjects.

The Section on Production Engineering, which occupies nearly half of the book, has chapters on Air-Gas Lift, on Gas-Oil Ratios, on Electricity in Oil Fields, on the Handling of Congealing Oils and Paraffin, on Increasing the Extraction of Oil, on Sucker-Rod Strains and Stresses, and on Deep-Well Drilling Technique.

The second section contains a report of a round table conference on Petroleum Engineering Problems, and is followed by the Refining Technology Section, which is divided into chapters on Distillation Methods, on Heat Utilisation, on Refining Control, and on Refinery Products and Problems.

The two chapters on Production deal (1) with the various fields of the United States, and (2) with Foreign Production, and the section on Petroleum Economics discusses Products, Crude Oil and Export Trade. The book closes with two chapters on Engineering Education, one on the Handling of Graduates and the other on Graduate Courses.

Upwards of two hundred technologists and engineers, the majority of whom are all well-known in the petroleum industry, have participated in the production of the papers or have taken part in the discussions and the book forms a valuable collection of information regarding up-to-date developments in the various fields of petroleum technology. GEORGE SELL.

BOOKS RECEIVED.

THE BRISTOL AND SOMERSET COALFIELD. THE CARBONISATION OF "PARKER LARGE GAS" COAL. Dept. of Scientific and Industrial Research. London, H.M. Stationery Office, 1928. Pp. 35. 1s. 6d. net.

The twelfth report of the series on the Physical and Chemical Survey of the National Coal Resources deals with the carbonisation of the "Parker Large Gas" Coal of the Bristol Coalfield.

In the low-temperature tests the temperature of carbonisation was 625° C., and the yield of products per ton of dry coal amounted to 15.6 cwt. coke, 14 gals. tar, 72 gals. liquor, 10,990 cu. ft. (46.2 therms) gas, and 16.3 lbs. ammonium sulphate.

THE INTERNATIONAL TEMPERATURE SCALE. George K. Burgess. Washington, U.S. Government Printing Office, 1928. 5 cents.

This is a reprint from the Bureau of Standards Journal of Research, October, 1928, and gives the Definition of the International Temperature Scale, together with the Recommended Experimental Procedure.